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IMPORTANCE AND STATUS OF THE SUPERCONDUCTING SUPER COLLIDER

JOINT HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES

AND THE

SUBCOMMITTEE ON ENERGY AND WATER DEVELOPMENT

OF THE

COMMITTEE ON APPROPRIATIONS UNITED STATES SENATE

ONE HUNDRED SECOND CONGRESS

SECOND SESSION

ON THE

IMPORTANCE AND STATUS OF THE SUPERCONDUCTING SUPER COLLIDER

JUNE 30, 1992

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IMPORTANCE AND STATUS OF THE SUPERCONDUCTING SUPER COLLIDER

TUESDAY, JUNE 30, 1992

U.S. SENATE, COMMITTEE ON ENERGY AND NATURAL RESOURCES, AND THE SUBCOMMITTEE ON ENERGY AND WATER DEVELOPMENT, OF THE COMMITTEE ON APPROPRIATIONS,

Washington, DC.

The committees met, pursuant to notice, at 9:42 a.m. in room SH-216, Hart Senate Office Building, Hon. J. Bennett Johnston, Chairman of the Energy Committee, presiding.

OPENING STATEMENT OF HON. J. BENNETT JOHNSTON, U.S. SENATOR FROM LOUISIANA

The CHAIRMAN. The hearing will come to order.

At $8.3 billion, the superconducting super collider is on budget and on time. While this is a lot of money, of course, it represents only forty-three-thousandth of the Federal budget. It represents a saving, if this project is canceled this year, of only $4.3 billion. Let me repeat that. If this project is canceled this year, considering the amount of money that has already been invested, considering that which is for inflation, it represents a saving of only $4.3 billion. Not $12 billion, as we have heard, not $20 billion, as we have heard, but $4.3 billion.

If we should cancel this project this year and 22 others of equal size, then cumulatively it would represent a savings of 1 percent of the budget. Or putting it another way, if we canceled all the projects in the energy and water appropriation bill this year, all of the science projects, it would represent one-five-hundredth of the budget.

Now, Congress frequently acts—or sometimes acts—impetuously, with the emotion or the politics of the moment, only to come in in the cold light of day and recognize the gravity of the mistake that is made. And Congress frequently reverses itself. I hope today is that kind of day when Senators, whichever side they have been on in this great national issue, will reconsider this very vital project for the United States today. All of us want to send a signal that we are fiscally responsible, that we are for the balanced budget, that we want to bring down the huge amount of this deficit. But we all know that the real problem with the deficit is not science projects, which in this budget represent cumulatively one-five-hundredth of the budget. Everyone knows that the problem is entitlements, 60 percent of the budget and growing.

Now, that is where Congress needs to screw up its courage, needs to act, and needs to contain the growth of entitlements, not the scientific seed corn which the SSC represents, not the most important science project in America, in my judgment, but entitlements. So I say to my colleagues, let us not kill this project in the name of the balanced budget when it is not the culprit.

As this Nation struggles to become competitive in the world economy, the last thing we should kill is our basic science projects. What we should do is look at every science project, every single one of them from the SSC to fusion to the strategic defense initiative to the space station to energy research, all of it, to determine whether or not it—to determine what its purpose is, what its payoff is, and what its cost is; to determine what the scientific community thinks of it and determine why it is important to America.

Today's panel, only four in number, is as learned and as distinguished as any panel who has ever appeared before the Energy and Natural Resources Committee or the Energy and Water Appropriations Subcommittee. They are here to answer those questions. Unlike some scientific projects which are being funded today, this project is on time and on budget—in fact, with any luck it will be under budget—it is broadly and strongly supported by the scientific community, and it is vital to America's interests.

I hope my colleagues in the Senate will see it that way after today's testimony. I look forward to this testimony. It will, I believe, be as interesting as any we have ever had.

Senator Wallop.

STATEMENT OF HON. MALCOLM WALLOP, U.S. SENATOR FROM WYOMING

Senator **Wallop**. Thank you, Mr. Chairman, and let me echo your words as to the relative cost of this incredible project in budget terms. There are few things that Government can do, and advancing knowledge is one of the few creative things that Government can do. As you know and we both know, Government can be proactive, it can be reactive, it can be detractive, but it can rarely be creative. And to advance America's scientific and technological position in the world is one of the most important decisions that we can possibly have in front of us. To shun it would be a shame. To accept it would be to advance this Nation's and this world's knowledge of the basic physics which surrounds us.

I hope, like you, that the Congress can reconsider where it has gone and go back to where it was going, be, for once, creative, drop the reactive posture that is putting this project in jeopardy.

Thank you, Mr. Chairman.

The **Chairman**. Thank you very much, Senator Wallop.

Senator Bumpers.

STATEMENT OF HON. DALE BUMPERS, U.S. SENATOR FROM ARKANSAS

Senator **Bumpers**. Thank you, Mr. Chairman.

First, I want to thank you for holding this hearing today to review the super collider program. We have before us a very distinguished panel that should help to shed some light on this difficult issue. But Mr. Chairman, I must note however, that our witnesses, as prestigious as they are, only represent one side of the debate on this issue. Accordingly, only one basic message is going to be coming from the witness table today.

As all the Senators here know, there are many in the scientific community and elsewhere that are opposed to the super collider, yet their voices and that point of view will not be heard today. Hearing both sides of this issue from experts I believe would have beneficial effects on all of us, particularly those who may not have made up their minds on this important issue. We would all lose if only critics were testifying here today. Likewise, we all lose with only supporters testifying.

The question the Senate has to address on the super collider is not whether this is good science. Considered in isolation, I, for one, would like very much for particle physicists to have the funds they need to address fundamental questions such as the origin of matter. But I would also like for medical researchers to have all the funds they need to address the fundamental questions such as the functioning and malfunctioning of cells in the human body, the origin of birth defects, the functioning of viruses, and other vital issues and bioscience. I would like materials scientists to have all the funds they need to address the fundamental questions like the origin of superconductivity and the possibility that this physical state could be reached at room temperatures.

I would like all of these things, and more. But, Mr. Chairman, it is an unassailable fact that this great Nation of ours simply cannot afford them all.

It is a colossal human tragedy that of all the grant requests the NIH receives, only 24 percent get funded. Twenty years ago, that percentage was 70 percent. I know that one of the concerns of particle physicists is that failure to fund the SSC would discourage young people from entering particle physics. Well, what about young people entering the medical profession and medical research? Are they, too, being discouraged from entering their fields? And the fruits of medical research have direct applications in the real world, which cannot be said for the super collider.

All fields of scientific endeavors are suffering cuts. That is one of the bitter legacies of 12 years of the delusion that we could cut taxes, raise defense spending, and balance the budget. I remember one very perceptive candidate in 1980 saying that was voodoo economics. That was one time he was right.

We in Congress are constantly hearing that what is needed is a balanced budget amendment. Now, you can put words in the Constitution, but we still are left with the task of adjusting spending and revenue so that the budget comes into balance. And this means spending cuts that are going to be very painful. Those who support a balanced budget amendment and constantly lament profligate spending almost to a person favor both the super collider and the space station. It is an irreconcilable contradiction. We cannot solve our deficit problems without terminating a lot of programs, including some such as the SSC that would otherwise be highly desirable.

Some cuts in research areas that directly benefit people are going to be made. We have seen the cost estimates for the collider more than double in 3 years, yet we are told it must continue. Why, in a period of fiscal austerity, are we in effect giving the collider a blank check? Everything we would like to find and understand that the SSC would reveal will still be there 10, 20, or 50 years from now. It is not going anywhere. It will still be there waiting to be discovered when we put our fiscal house in order and can consider funding projects such as this. We might even get the answer from the CERN project in Geneva without spending another nickel. And certainly, the more advanced technology of that time should reduce the super collider's gigantic cost.

A program with a likely life cycle cost of over $20 billion that has no direct benefit for the economy or our people should be a priority item. There are no credible assurances that the cost estimates we are presenting today will not double again. The cost uncertainty is one of the many reasons why Japan has refused to commit to it. Japan has so little confidence in DOE's cost estimates they are conducting their own cost estimates. And why? According to the Japanese Government source quoted in the Japanese press, "it is highly likely that the $8.25 billion figure the U.S. side has submitted may increase at some point during construction."

Last year in the debate on my amendment to delete funding for the collider, vigorous arguments were made that our, "participating partners" would say we were reneging. Now, I invite anybody to calculate and total the contributions to all SSC's illusory participants.

There is no better indication of the SSC's irrelevance to a sound economy than the fact that Japan has steadfastly refused to commit to the project despite repeated high-pressure lobbying by this administration. Even face-to-face salesmanship by President Bush in January failed to budge them.

At one time, we were told that Japan would contribute up to $1.6 billion toward the cost of the collider. Yet all Japan has agreed on so far is to study the issue. Japan's opinion of the super collider is best revealed by the fact that had they decided to participate in the project it would have been funded out of their foreign aid budget, not their science and technology budget.

If Congress cannot now hear the voice of people calling for change and deficit reduction, the we deserve every ounce of anger we are being subjected to. It is time for us to face the hard choices, not duck them. We were all elected to do a job. And as never before, it is now time to do it. I hope we here today will keep from focusing exclusively on the super collider itself and remind ourselves of a larger problem; namely, the budget and the economic climate in this great Nation.

Thank you, Mr. Chairman.

[Material submitted for the record by Senator Bumpers follows:]

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June 24, 1992

The Honorable James D. Watkins
Secretary
Department of Energy
1000 Independence Avenue
Washington, D.C. 20585

Dear Mr. Secretary:

On June 15, 1992 we had a "Dear Colleague" letter delivered to the 435 elected officials of the House of Representatives. Our letter pointed out that while the Department has consistently professed to Congress that the SSC is on time and under budget, internal DOE communications indicated otherwise. We specifically pointed to language in a January 24, 1992 letter signed by Deputy Secretary Henson Moore which stated that cost growth problems in conventional construction "were continuing and may even be getting worse."

On June 17, 1992 you sent a letter to us in response to our "Dear Colleague." While our initial intention had been to let your claims pass, the wide distribution you caused your letter to have, including its insertion into the Congressional Record, compels us to respond.

Proponents of the SSC are attempting to explain the overwhelming repudiation it received in the House as the SSC simply falling victim to a temporary balance-the-budget fever. However, that explanation suggests that the "fever" will pass. The fact is that there is a serious, long-term federal budget situation that demands making tough choices, and, further, the SSC is a particularly vulnerable target because of the pattern of deceit the Department has shown in its efforts to sell this project to Congress. As the June 17 vote shows **the project's reality finally caught up with the project's hype.**

While there is no question that you have performed signal service to the nation in your career, the Department of Energy has not one shred of credibility left for its claims regarding the Superconducting Super Collider. A little history may be instructive on this point.

* The first example we would point to is DOE's claims about the accuracy of the SSC's cost estimate. On April 7, 1987 Dr. Alvin Trivelpiece, then the Director of the Office of Energy Research at DOE, testified on the costs of the SSC before the House Science, Space, and Technology Committee. At that time he challenged critics of the Department's cost estimate saying that "We believe these numbers are accurate to within 10 percent; that they are conservative; that the $4.4 billion is not only accurate to within 10 percent, it's conservative."

Dr. Trivelpiece went on to say, "I think it is probably the best analyzed project ever brought forward by the Administration to the Congress in terms of knowing what it takes to do it, what the feasibility is and how long it's going to take and how much it's going to cost." Of course three and a half years of study later (January 1991) the Department's new cost estimate was released, $8.25 billion, with all the same rhetoric about being accurate and conservative. Within six months of that much ballyhooed baseline budget, the SSC Lab was trying to figure out why that accurately plotted project has magnets "missing" from the collider ring to make it complete--the cost for this little oversight (and it is not the only one discovered to date) will be approximately $10 million.

The second example we offer of the Department's misleading conduct towards Congress on the true situation at the SSC relates to foreign contributions. In October 1990, the Department prepared a decision document for the White House discussing the possibility for receiving foreign contributions to the project. That document candidly discussed the likely foreign contributions and concluded, "we believe that we are unlikely to meet the Administration's goal for non-Federal participation (one third of the total project cost) in the foreseeable future." The report also concluded that, "The U.S. may, therefore, with Texas support, need to carry most of the cost of constructing the SSC for several years (significant contributions may not be forthcoming through the mid-1990s)."

At precisely the same time as that candid report was being forwarded to the White House, your Department was finalizing the project baseline budget for a January 1991 delivery to Congress. That baseline budget is built upon a projection of foreign contributions totaling almost $800 million through fiscal year 1996, which sounds like the mid-1990s to us. Candor on foreign contributions apparently stops at the edge of the Executive branch.

As of today, June 24, 1992, the Department still has no substantial foreign contributions and your promises of impending agreements ring hollow after more than three years of such claims. (For example, you signed a letter dated June 27, 1989 to a key House Appropriations Committee member encouraging full funding of the SSC request, "On-going discussion with the Japanese, begun eighteen months ago, are entering a critical phase... With a strong signal [of support] from Congress, we will be able to move aggressively and I believe successfully to consummate the discussions that began eighteen months ago, and by this time next year to report to you that we have made excellent progress towards being fully subscribed.")

A final illustration of misleading statements by the Department to Congress can be drawn from a briefing provided to Congressional staff just two days before the House vote on H.R. 5373. At that briefing, Dr. Raphael Kasper, Associate Director of the SSC Lab, used a chart to illustrate the wonderful managerial performance of the SSC in the field of conventional construction. The first example he pointed to was the work done on the Magnet Development Laboratory (MDL). He said that the baseline budget for the MDL was $12.6 million and that it was built for $12.6 million. His claim, made before a room full of Legislative Assistants who would brief Members of Congress on the SSC, was interesting but inaccurate.

In fact, the MDL is a textbook example of management asleep at the switch. According to documents that came out of the office of Mr. Jon Ives, Associate Director at the SSC Lab for Conventional Construction, the MDL suffered a cost overrun of more than 20% in construction and management services. The building was resited four times, the walls of the second floor were moved out twice and an artesian spring was discovered bubbling under the foundation. As you are well aware, the situation has attracted the attention of the Department of Energy's Inspector General and a report is long overdue out of that office.

We could cite many, many, many more examples of Departmental or SSC Lab employees hyping the SSC project or engaging in the worst kind of word-games to avoid providing straight, honest answers to tough questions. However, we wish to respond to your specific charge that we misused and mischaracterized Deputy Secretary Henson Moore's letter of January 24, 1992 relating to cost problems in conventional construction.

The Moore letter reads in part, "You have known about this problem for some time and have not addressed it," and "(t)oday, I have learned that the overrun problems are continuing and may even be getting worse." Your letter dated June 16 asks us to believe that this language is a demonstration that "we have a good management system that identifies potential problems, takes corrective action immediately, and monitors the performance of the corrective action."

We wish your assertion were true, but it is demonstrably false and our interpretation is borne out by the history of the Department's management of conventional construction and its inability to bring either the prime contractor, Universities Research Association (URA), or the architect-engineering/construction management (AE/CM) contract with Parsons-Brinckerhoff/Morrison Knudsen (PB/MK) under control.

History of Cost and Contract Problems in Conventional Construction

1. The AE/CM contract bid package from PB/MK was reviewed by the Defense Contract Auditing Agency (DCAA) in the summer of 1990. In July 1990, DCAA officials phoned a DOE contracting officer in Texas to communicate to him that the conventional construction bid was not acceptable. DCAA's formal report concluded that $159 million out of a $312 million bid lacked adequate documentation to support its cost projections. Their analysis reads, in part:

> "The proposal has not, in all respects, been prepared in accordance with the DEAR (Department of Energy Acquisition Rules) and appropriate provisions of the FAR (Federal Acquisition Rules). **In our opinion, the cost or pricing data submitted by the offeror are not adequate. Therefore, we do not consider the proposal as it pertains to subcontract costs to be acceptable as a basis for negotiation of a fair and reasonable price."** (Emphasis added to the original.)

2. The prime contractor on the project, URA, received the DCAA report. They determined that it would be inefficient to have PB/MK validate projected subcontract costs in line with DEAR and FAR provisions. Further, since the PB/MK bid had simply adopted the construction subcontract cost projections made by the SSC Lab (run by URA), URA had no incentive to see those numbers reevaluated.

Certainly the AE/CM believes that URA knew even before the contract was signed that construction costs were unlikely to stay at the baseline projections. According to minutes of a URA-PB/MK meeting of September 13, 1991, PB/MK asserted "the SSCL was made aware that the AE/CM costs were well off the baseline... last fall (1990), PB/MK presented detailed information to SSCL representatives... the presented information clearly showed the PB/MK forecast of where costs were headed... The message was clear then."

3. The Department's top official on the SSC project, Mr. Joseph Cipriano, received the conventional construction contract consent package on October 26, 1990. This package included the DCAA report which was so critical of the PB/MK bid. Despite that report, on December 21, 1990 Mr. Cipriano approved the award of an AE/CM contract to PB/MK.

4. Within two months of approving that contract, Mr. Cipriano wrote in a secret report to you dated February 22, 1991 that, "the lab still hasn't gotten in charge of the AE/CM and we have the potential for a $50 million overrun there if things continue as they are. It is still avoidable and we will be working the issue real hard." Note that the language "the lab still hasn't gotten in charge" implies that the managerial problems had been continuing for some time.

5. At the same time that Mr. Cipriano was writing to you regarding the possibility of a $50 million overrun, SSC Lab officials were projecting much higher overruns. A February 25, 1991 lab memo indicates that the total overrun on AE/CM activities would be in the range of $165 million.

6. By the end of the Spring of 1991, DOE, URA and PB/MK put in place a plan to bring these cost problems into line.

7. Despite this plan, on June 21, 1991, in a meeting between PB/MK and SSC Lab officials, PB/MK made the first cut of its own (so far as documents provided to the Subcommittee show) at projecting cost overruns in conventional construction and those numbers indicated an overrun of $294 million.

Then, on September 13, 1991 the AE/CM contractor finished its cost projection model and formally presented to the SSC Lab a projection of cost overruns in conventional construction of between $73 million and $383 million.

8. In October 1991, as mentioned in the Deputy Secretary's letter, Mr. Moore visited the SSC Lab, met with URA and PB/MK officials, and another plan was crafted to avoid these huge projected overruns.

9. Despite this plan and the Deputy Secretary's personal intervention, Mr. Cipriano wrote in a letter dated December 30, 1991 to URA expressing the Department's concern about the prime contractor's "ability to manage and control the effort and cost" in conventional construction. That same letter noted that "Due to the seriousness and long-term nature of the concerns with the PB/MK performance and URA's management of the PB/MK subcontract, DOE is considering a wide range of potential corrective actions." At that time, Mr. Cipriano demanded a plan from URA to handle the "deficiencies" identified by the Department and the Inspector General.

Mr. Cipriano's letter goes on at some length about the deficiencies noted by DOE and the Inspector General. "(C)onstruction costs are excessive due to numerous user changes, unsatisfactory work authorization and Notice to Proceed process, incompatibility of cost codes and cost accounting between PB/MK and SSCL, incompatibility of cost system and finance system used by SSCL, and untimely cost reports prepared by SSCL. The IG also noted AE/CM costs are excessive due to numerous user changes: "Fast Tracking", PB/MK's excessive organizational structure, inability of SSCL to control PB/MK costs, continuation of funding and expenditures (although SSCL has not approved PB/MK's annual work plans), a poor working relationship between PB/MK and SSCL, and the nature of the subcontract (cost plus award fee) providing little incentive for contractors to design within baseline cost estimates."

Note that the last item mentioned by Mr. Cipriano in his list of deficiencies is the very nature of the contract for AE/CM services. But that was a contract Mr. Cipriano approved. That was the contract based on a bid that the DCAA warned the Department was unacceptable as a basis for a negotiation of a fair and reasonable price. That was a contract that within two months of approval, you were being warned showed signs of cost growth.

10. Just twenty-five days after Mr. Cipriano's December letter, then Deputy Secretary Moore sent his own letter again demanding a plan by URA to get costs under control. URA's response was a two page letter containing the usual promises of searching for cost savings and more aggressive management.

In sum, the Department had warning signs of trouble in the conventional construction program that went back to July 1990, approved a contract which DCAA had questioned, approved that contract even with cost problems already showing up (as shown in Mr. Cipriano's February report to you), and subsequently intervened to help craft (at least) two plans to bring the conventional construction program into line. The result? The situation deteriorated at every turn. You will forgive us if we find it hard to accept your assertion that the January 24, 1992 letter by the Deputy Secretary is proof of a crack management system.

In its latest claims, Departmental and URA employees have said that a plan to get conventional construction overruns under control has been approved. However, the only version of the latest plan that has been made available to our Subcommittee indicates that the "plan" is built on altering the escalation rate and moving elements of the AE/CM's work out of the AE/CM package. That does not mean the work disappears or that any real savings are realized, simply that the work and the costs will not be handled as part of the current AE/CM contract.

We could discuss the claims of being "on time and on budget"(though for quite some time the slogan was "on time and under budget"), the efforts to sole source contracts abroad, the problems with geology that have forced the SSC Lab to move the huge detector halls, or the dozens of configuration control board requests. We could remind you of your claims, contained in a letter delivered to us on May 8, 1991, that DOE had no chance to see or comment on GAO's work when in fact DOE had made such comments and some of them were incorporated into GAO's report on the SSC. We knew this because the Department's written comments were in the possession of our Subcommittee. We could remind you that last July you sent us a letter stating that all relevant materials in response to our document requests had been delivered; within a month we had discovered that secret, back-channel reports from Mr. Cipriano to you had been withheld from the Subcommittee.

We could discuss all these things, but we believe that we have sufficiently demonstrated two points: the Department of Energy has a credibility gap on the SSC and the Moore letter is a clear signal of a management system that is not in control of a multi-billion dollar project.

Sincerely,

Howard Wolpe
Chairman
Subcommittee on
Investigations & Oversight

Sherwood Boehlert
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May 21, 1991

Dr. Richard A. Carrigan, Jr.
Head, ORTA
FERMILAB MS-208
P.O. Box 500
Batavia, Illinois 60510

Dear Dr. Carrigan,

Bob Park sent me a copy of your letter to him dated May 6, 1991, taking him to task in referring to testimony by DOE Deputy Secretary Henson Moore as ill-advised. Mr. Moore stated "Magnetic Resonance Imaging is a spin-off" from the activities of accelerator research done at Fermilab and SSC. When I testified subsequently at the same hearing, I inserted in my oral presentation the following. "As an expert in magnetic resonance I wish to correct a statement in the testimony of the Honorable Mr. Moore. I can state categorically that MRI is not a spin-off from SSC related activities". *1

For your information I may add that Leon Lederman was seated on my left, as he testified at the same hearing. Leon respected my testimony, as I did his.

From the facts stated in the main body of your letter, the following statement could be derived: "The superconducting wire technology in the U.S. has greatly benefited from the work done by and for Fermilab and SSC. This in turn has improved the equipment used in MRI". The extrapolation of this factually correct statement to the testimony by Mr. Moore that "MRI is a spin-off of Fermilab and SSC" is unwarranted, and indeed ill-advised. It completely ignores the essential contributions by a very large number of physicists who have brought MRI to fruition. MRI would be alive and well today, even if Fermilab had never existed. Superconducting magnets, manufactured, for example, by Oxford Cryogenics, are entirely adequate and used in many MRI installations in Europe and elsewhere.

In the interest of the unity of physics, which we all wish to promote, excessive claims by an particular subfield should be avoided. I hope that in the future the technical information that is permitted to filter to the top administrative echelons of DOE is more carefully worded. I ask for your cooperation in this respect.

Sincerely yours,

Nicolaas Bloembergen
N. Bloembergen

NB:jes
cc: R. Park
    L. Lederman

June 4, 1990

Mr. Malcolm W. Browne
The New York Times Company
229 W. 43rd Street
New York, NY 10036

Dear Mr. Browne:

I would like to congratulate you on your article on the Supercollider in the Science Times, May 29, 1990. I do so not simply because of either your or my views on SSC, but because the piece was quite clearly well researched and well written. I would like to add some material to your files if I may; they are enclosed, and should be more or less self explanatory.

I would also like to add some brief points for your consideration, both as Past President of the American Physical Society and as a physicist:

(1) The Supercollider is a heroic, but very specialized, experiment in science. In physics today there are at least 18 identifiable subfields, in the American Physical Society there are 40,000 numbers. Particle physics represents about 8% of the field, and in spite of its proponents' suggestions is surely not the only important area, nor most fundamental. Particle physics is also specialized to the extent that it has not made and cannot, by this nature, make an impact on most other areas of physics, on chemistry, on biology on electronics, or any other sciences except perhaps astrophysics and cosmology. As to funding in a climate of limited resources, perhaps 1000 particle physicists might be served by the SSC, at a construction only cost of \$5 x 10^9. This amounts to a 10 year grant of ~~5 million dollars to each individual particle physicist involved~~; the average grantee from NSF is struggling for a ~~1 year grant of \$40,000.~~

(2) The promotion of the Supercollider caused serious problems in the American Physical Society, as you astutely noted in your article. The manner of promotion and costs caused significant divisiveness. As president of APS in 1989, and as president-elect before I put my own opinions of the SSC aside and concentrated on holding the Society together, successfully I believe. I enclose part of my retiring APS presidential address at Washington, April 17, 1990. The main source of dissension was the manner in which the SSC was promoted. The issue is not simply big science vs. small science but that, in the view of many members, the extravagant representation to the public of the potential fruits from the SSC was fictitious and ethically irresponsible,

[redacted]

Once again, credit to a good piece of reporting.

Sincerely yours,

James A. Krumhansl
Horace M. White Professor
of Physics

JAK:cfl
Enclosures (3)

The CHAIRMAN. Senator Domenici.

STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

Senator DOMENICI. Thank you, Mr. Chairman.

First, Mr. Chairman, let me say that some very distinguished members of the scientific community have impressed me in the last few days immeasurably. I have had what I perceive to be some of the best who stand conceivably to lose money in their research areas who have come to me and said do not cancel this project. And the reasons were very, very profound. In fact, I congratulate them. They think bigger and better than a lot of politicians.

I was not for it, said one great scientist. But it will be worse for the United States of America down the path as it has gone on this super major science project, to cancel it. The ramifications of cancelling this is just another indication that America cannot do.

I concur. I think they are absolutely right. Everyone on this committee knows that this Senator—this Senator—is as big a supporter of science as there is in the U.S. Senate. And I must say I have reason to I have two national laboratories in my State. I think they do great work. In a sense, they stand to lose, Mr. Chairman, perhaps over the short run because we are going to fund SSC, because much of SSC comes out of the nondefense appropriations for laboratories, not only the ones in my State but everywhere. But I frankly believe that this country cannot afford to say that we cannot afford this project. That is absolutely a bum rap for America. We can afford it and we ought to pay for it and we ought to do it.

For those who run around and say this will save our fiscal policy, they just refuse to look at the facts. The facts are that the discretionary appropriations of this Government, and certainly those of science in this Government, have almost an infinitesimal effect on the deficit of this country, so that when I hear a national news reporter after the House vote say we are beginning to get our fiscal house in order because we are not going to pay for this program, we truly need to get the message across.

It is not this kind of program that is breaking the back of America's taxpayer and fiscal policy. It is precisely our refusal to control, reform, and in any way change mandatory programs called entitlements that we put on the books and we end up with American people assuming under all circumstances they are entitled to that forever.

If you take Social Security out of this budget, 225 to 250 mandatory programs are growing at 9 percent a year compounded. Two of them are growing, one at 30 percent a year, one at 15 percent a year, and they are both gigantic. One is Medicaid and one is Medicare. That is what we have to get under control.

If we were to permit the mandatory expenditures of our Government to grow at the rate of inflation, starting 5 years from now—we give it 5 years to get there—we will save $700 billion by the year 2002 off of current policy. Not $7 billion, $700 billion within 10 years you will save off the current policy line of entitlements, absent Social Security, if you finally get them in 5 years to the place where they are growing no more than inflation. That sounds incredible, but it happens to be true.

We will have to do that or the country will literally be broke, because to the extent we do not control it in the Federal budget we will not control it in the marketplace, and health care alone will break the United States of America in the next 12 to 15 years, absolutely.

Now, Mr. Chairman, having said that, if the United States of America, having more scientists than any country in the world, having the best scientists and Ph.D.'s in the world and more of them, having more physicists than any country in the world and better, if we cannot afford to give them the most critical research instrument of their esteemed professions, then what are we as a Nation?

Some say do little physics, do little projects. We have two giant projects going, and we ought to keep them both going. One will tell us about the origins of matter, and that is this one. The other one is the genome, or genetic basic research program of this Nation which will map the genes of the human being. Some even say that is too big, give it to little science. Why would we not do that one which will give us the essence of the genetics of humanity and hand it to the researchers to perfect? This will do something similar in the origins of matter.

So, Mr. Chairman, I think we ought to proceed with the hearings. I regret that my friend from Arkansas thinks we are only hearing from one side. Frankly, I heard from all sides three different occasions. I thought we put this one to rest a long time ago and made a commitment. I think we ought to live up to it and I look forward to hearing from the four witnesses that are here.

Thank you very much, Mr. Chairman.

The CHAIRMAN. Thank you.

Senator Akaka.

STATEMENT OF HON. DANIEL K. AKAKA, U.S. SENATOR FROM HAWAII

Senator AKAKA. Thank you very much, Mr. Chairman. I look forward to the hearing this morning, the superconducting super collider. And especially, it is important to the leadership of science in our country.

Mr. Chairman, I have a longer statement that I would like to have entered into the record, and I will be brief.

The CHAIRMAN. Without objection.

Senator AKAKA. There is no doubt of the important role scientific research plays in our economic development. In fact, basic science programs like the SSC provide opportunities for many promising spinoff applications. However, we are all aware that the House of Representatives recently voted to terminate the SSC. The House debate has raised several issues which must be addressed if support for the program is to continue.

In these lean fiscal times, budgetary constraints have become a primary concern. The SSC is no exception. The Department of Energy has claimed that the project is on schedule and within its $8.25 billion budget. However, testimony from the General Accounting Office before the House committee raised serious questions about management and accounting of this program.

Concerns have been raised over the lack of foreign participation. To date, India and Albania have pledged $40 million of the expected $1.7 billion foreign contribution. Even Japan, with its interest in high-energy physics, would provide funds out of its foreign aid account, not its science and technology budget. The lack of foreign assistance could increase the U.S. cost of this project.

Despite the lack of foreign participation, foreign subcontractors are expected to build several components of the SSC. The GAO testimony also suggests that foreign suppliers will further reduce the multiplier effect of the investment on the U.S. economy.

Mr. Chairman, I support science and technology research and development. However, there comes a point when costs begin to outweigh benefits. I hope today's hearing will address these concerns so that we can assure the American public that this project will be a wise investment of our tax dollars.

Thank you very much, Mr. Chairman.

[The prepared statement of Senator Akaka follows:]

PREPARED STATEMENT OF HON. DANIEL K. AKAKA, U.S. SENATOR FROM HAWAII

Mr. Chairman, we are here today to address the future of the Superconducting Super Collider (SSC) and its importance to the leadership of the United State in high energy physics.

The SSC, a high energy particle accelerator, was envisioned to research the basic nature of matter. The information obtained from this program would assist scholars in better understanding the unknowns of the universe and improve our fundamental knowledge of energy. Development of the SSC would help keep America in the forefront of scientific research and provide related benefits in other fields.

As a former teacher, I am fully committed to our investment in scientific research and development. In fact, basic science research programs often provide opportunities for many spin-off applications. However, the recent debate in the House of Representatives has raised several concerns which must be addressed if we are to continue support for the SSC. We are all aware that the House recently voted to terminate this program.

In these lean fiscal times, budgetary restraints have become a primary concern. The SSC is no exception. The Department of Energy (DOE) has claimed that the SSC project is on schedule and within its $8.25 billion budget. However, testimony from the General Accounting Office before the House Committee on Science, Space and Technology's Subcommittee on Investigations and Oversight raised serious concerns about the lack of an integrated system for monitoring cost and schedule performance. The accounting deficiencies highlighted by GAO contradict DOE's claim and makes it difficult to validate whether the program is within budget.

For example, on January 24, Deputy Secretary of Energy, Henson Moore, sent a letter to Mr. Roy Schwitters of University Research Associates which discussed problems of cost overruns for conventional construction. Secretary Moore's letter stated, "conventional construction should be the easiest part of this project. With the recession and availability of architects, engineers, and construction companies, there is no reason for overruns, especially in the administrative area . . . This shows to me a lack of management ability on the part of URA when it comes to conventional construction." This letter substantiates the claim that the Department is experiencing problems in management and that cost overruns could jeopardize the program.

Questions have also been raised over the lack of foreign participation. DOE is seeking approximately $1.7 billion in foreign contributions. To date, only $50 million have been pledged from India and Albania. Even Japan, with its interest in high energy physics, would provide funds out of its foreign aid account, not its science and technology budget. Without foreign assistance, the cost of this project to the United States could increase an additional $500 million or more.

Despite the lack of foreign participation, foreign subcontractors will build several components of the SSC. The superconducting cable, which is critical to the use of superconducting magnets, is a good example. The development of this cable is expected to revolutionize the transfer of energy. Currently, out of the seven suppliers subcontracted with the SSC Laboratory, three of the suppliers have plants in the United States, four do not. The GAO testimony suggests that "foreign suppliers will further reduce the multiplier effect of the investment on the U.S. economy."

Mr. Chairman, I support science and technology research and development. However, there comes a point when costs begin to outweigh benefits. Economists call it the law of diminishing returns. I hope today's hearing will address these concerns so that the American public can be assured that the SSC is a sound scientific and economic return on our investment.

The CHAIRMAN. Thank you, Senator Akaka.

Senator Craig.

STATEMENT OF HON. LARRY E. CRAIG, U.S. SENATOR FROM IDAHO

Senator CRAIG. Mr. Chairman, thank you for convening this hearing this morning. My dad, all of his life, was a farmer and a rancher. And when I was elected to Congress he said: "What kind of a job is it?" And I said: "Well, it is indoors and no heavy lifting." Let me tell you, ladies and gentlemen, the no heavy lifting part has created a $1.4 trillion debt—excuse me—$1.4 trillion budget, a $4 trillion debt and a $325 billion deficit. That is the no heavy lifting on the part of the U.S. Congress and the American people. So today, two important things are happening. One is a vote on a balanced budget amendment to our Constitution. That is heavy lifting, folks. Another one is this hearing to establish priorities. That is heavy lifting.

Now, I am one of those who is not at all unwilling to face tough votes. I am going to vote for a balanced budget amendment to force this Congress into reality. And then under that reality, I would vote for this project because of where I place it in priorities for this country, which means I would then have to be recorded as voting against other kinds of programs that someone else would put in a different priority. The great tragedy that we are thrusting on the American people today is that we are not facing any of those priority making decisions. We are suggesting that we can be all things to all people.

That is going to end right quickly, I hope during my tenure in office. Because I am ready to make those tough choices and this committee had better be ready to and this Congress had better to be ready to. And if we do not, Mr. Chairman, the American people are going to say we had better get some new folks back there to do the heavy lifting.

Tough choices. Let us make them. This is an important project. I would put it high on the priority list.

Thank you.

The CHAIRMAN. Thank you, Senator Craig.

Senator Wellstone.

STATEMENT OF HON. PAUL WELLSTONE, U.S. SENATOR FROM MINNESOTA

Senator WELLSTONE. Thank you, Mr. Chairman.

Let me try and be very brief because I think we ought to get to the panel of experts. And I do have an open mind, which is what I think you have asked of me and others. I cannot resist, and I promise everybody here I will take just a minute or two responding to what has been said.

I listened to Senator Craig, and let me just respond to what he said about the heavy lifting. We all have our analysis about what we ought to do in order to move our country forward on economic performance. I would argue that you might want to look at entitlement programs, also might want to look at further transfer from military to domestic, also might want to look honestly at how we raise revenue, if we are serious about both reducing deficit and investing in the economy.

The point I am trying to make, Mr. Chairman, is that those are the if's. But the reality right now is we are faced with these other kinds of choices. I am certainly interested in the science value and the technology value and the economic value of SSC and what it is all about. By the same token, we are faced with the choice of whether you fund this or whether you fund the women and infant children program, whether you have funding that deals with basic nutritional problem of people on the bottom, whether you fund education, whether you fund Head Start, whether you make sure children are fully immunized. These are the kind of choices that we are faced with.

So I just want to make it perfectly clear that I think the decision we have to make, not in the future when we get all this done but right now, is one of priorities and this is a very, very tough question. So I am glad you are here and I look forward to hearing what you have to say because I think this is going to be the decision I have to make, not just the value of what you are talking about but the value of what you are talking about relative to other kinds of programs which also deal with compelling needs and are also very valuable.

The CHAIRMAN. Thank you.

Senator DeConcini.

STATEMENT OF HON. DENNIS DeCONCINI, U.S. SENATOR FROM ARIZONA

Senator DECONCINI. Mr. Chairman, thank you, and thank you for including the appropriations side of this matter. I have supported in the past the superconducting super collider, because I believe, as has been said by the chairman and others, the importance of this research.

I do not know what I am going to do at this time, because as the Senator from Arkansas has pointed out, we have got some big problems. Senator Craig has pointed out heavy lifting, et cetera. Where do you place these priorities? Senator Wellstone just pointed out the WIC program.

I think two things, Mr. Chairman, and first I want to compliment you on your leadership in the area of energy and this committee and the Energy Committee and your consideration of important things from my State. I also think the Senator from Arkansas makes a good point. We ought to hear the other side. In my little State of Arizona one little university gets $900,000. This is very important to them. They are very dedicated to this. And I have heard from those professors and scientists. There are also several at that same university who think it should not be funded, for scientific reasons: The risk is too high, there are other priorities that they feel ought to be funded.

I am caught in a real dilemma. And I do not know if the chairman is considering doing this: When we had the dilemma of the *Seawolf*, what to do, I was for reducing the *Seawolf*. I ended up voting not to reduce it because the chairman of the defense subcommittee and the Appropriations full committee was able to come up with additional reductions from additional military programs, including the SDI and the B-2 bomber, that more than offset the *Seawolf*. I had to decide which way to go, so I went with the compromise, primarily because it was a greater reduction.

I do not know if the chairman is considering or if this committee is considering about some reductions in other programs, even outside this committee's jurisdiction. I do not find that out of line, considering what we have to do and the magnitude and the importance of this.

The witnesses, I have just had a chance to review three of their statements here, not all of them, and they are very impressive. I am not going to be able to stay for the entire meeting because of veteran's committees, but I am very impressed with their arguments. But we are not getting to the problem of—we cannot fund everything. We just cannot fund everything, no matter how important it is. And one priority for one party may not be the same priority for everybody. So I would suggest that we try to find some offset, and of course, the obvious place to ask the administration is in the defense area. We can reduce defense expenditures, certainly, by $600 million more than what has been proposed in the President's budget.

So it is a dilemma, Mr. Chairman, and I again thank you for holding these hearings, and I will look forward to their conclusion. And I urge that we have time to hear the other side. And I think it would be very, very constructive.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much, Senator DeConcini.

We begin today with Dr. Leon M. Lederman, who received his Ph.D. in physics in 1951 from Columbia University. In 1988, he received the Nobel Prize in physics for his discovery of the two neutrinos. Dr. Lederman was the director of Fermilab during the construction of the Tevitron. He is currently a professor of physics at the University of Chicago and serves on several advisory committees for the Department of Energy and the Governor of Illinois. He is the current president of the American Association for the Advancement of Science.

I have asked Dr. Lederman not only to talk about the SSC, but to introduce some of his colleagues in science who have taken the time and effort and expense to come here.

Dr. Lederman.

STATEMENT OF DR. LEON M. LEDERMAN, DIRECTOR EMERITUS, FERMI NATIONAL ACCELERATOR LABORATORY, BATAVIA, IL

Dr. LEDERMAN. Thank you very much, Mr. Chairman. I guess I was selected as a senior—no, not senior citizen. The new word is chronologically advantaged, I understand. You can write it down. If you cannot use it now, sooner or later you will be able to use it. I think it was George Burns who said "I am so old I remember when the Dead Sea was only sick."

[Laughter.]

Dr. LEDERMAN. I would like to introduce my colleagues who, many of whom have canceled travel plans, vacation plans, or are in trouble with their families, but we are all very grateful for the opportunity of being heard.

Seated in the front row there is Val Fitch, professor of physics and Nobel Laureate, Princeton University; Bob Adair, professor of physics at Yale University; Henry Kendall, a Nobel Prize winner from that institution in Cambridge called MIT; Nobel Prize winner John Peoples, director of the Fermi Laboratory, the place where I do my own research; Stanley Wojicki, who is the chairman of the High Energy Physics Advisory Panel and professor at Stanford; Nick Samios, who is the director of the Brookhaven National Laboratory; Steven Weinberg, theoretical physics Nobel Prize winner from the University of Texas at Austin; Bill Willis, Professor of Physics at Columbia University and leader in one of the large SSC construction detector programs; Barry Barash from Cal Tech, professor of physics; and George Trilling from Berkeley, also active in the detector program; Gary Feldman, professor of physics at Harvard and the chairman of the Division of Particles and Fields, and Melissa Franklin from Harvard, who is a professor of physics there, and if I have left out anybody—oh, Gerry Freedman, I am sorry, professor of physics at MIT and Nobel Laureate, and one of the discoveries of quarks. Yes, I made him move, and if I left anybody out it is probably because I hate them.

[Laughter.]

Senator BUMPERS. Dr. Lederman, you stick with physics. Do not ever get in politics.

Dr. LEDERMAN. It has been my privilege and pleasure to have testified before many committees of Congress on science, on high-energy physics, on science education, on science in developing countries—Nobel Prize winners are experts on all subjects, social security, length of women's dresses and so on, and never—never have I faced an issue so momentous, so crucial to the future of my community, and that is the community of science, and I feel this awesome burden of my heritage, my teachers and their teachers—I.I. Rabi, Enrico Fermi, Neils Bohr and Albert Einstein are all up there looking at me, and last night my hair was jet black.

It is my purpose to try and convince you that the supercollider may be as important an issue as you will face in these complex times in the U.S. Senate. It may seem to some of you as an expensive luxury in times of fiscal crisis, terribly abstract research with unpredictable utility in times of national stress generated by so many dire, so many immediate issues.

I would like to tell you with all the passion and logic I can muster that this issue of the SSC is much more than the SSC. It is much more than the possible demise of high-energy physics in the United States. It is about science, and about the flow of young people into science, into all sciences. It is about our future as a leading player on the world scene, and I would like your attention for the next 15 or so minutes so that I can explain.

As a professor at Columbia University I recall testifying before that hallowed institution, the Joint Committee on Atomic Energy, which supervised the transition of the Nation from science as key to victory in World War II to Science: The Endless Frontier, the report of Vanavar Bush, which set a fresh, new vision of replacing our traditional geographic frontiers with the endless frontier of scientific knowledge.

It was in this committee that nuclear physics and its successor, particle physics, was placed in the Atomic Energy Commission as a national trust. I testified in support of high energy physics in the 1950's, when it did not even have a name, in support of a 3-billion-volt machine called the cosmotron—we always had modest names for these things—and a 30-billion-volt AGS machine at the Brookhaven Laboratory, and later the 200-billion-volt machine at the Fermilab.

I participated in the slow but relentless growth and dominance of centrally-shared facilities. When Dwight Eisenhower in 1950 dedicated the Columbia cyclotron—and I was a graduate student there—it was the world's largest machine, at 400 million volts.

As a Ph.D I had a choice of some 21 front-line particle accelerator facilities on university campuses around the Nation. Slowly the number contracted as we closed machines as a community to apply the resource to fewer larger facilities. Coalitions formed.

Nine east coast universities—can you imagine that?—Harvard, MIT, and Yale, sitting down together to manage the Brookhaven Laboratory. Princeton and Penn combined Harvard and MIT combined to build machines. On the west coast, Stanford and Berkeley became national laboratories and absorbed the efforts of Cal Tech and the other universities on the west coast, and in the Midwest there was MURA and the University Research Association, a group of some 80 universities which manage Fermilab and the SSC.

Today, high-energy physics is carried out in two major U.S. labs, Fermilab and SLAC, and two smaller and older but still very productive labs at Brookhaven and Cornell. Note, incidentally, that the Brookhaven machine is over 30 years old, and the Fermilab machine is a brisk 20 years old.

"Big Science" is a term used to describe this evolution of shared complex facilities which are essential to the advance of a discipline. It includes telescopes and oceanographic vessels and supercomputers and synchrotron light sources. All science is relentlessly moving toward shared facilities, driven not by the megalomania of scientists—not that we do not have it—but by the increasingly difficult problem of ferreting out the secrets of nature and the increasing complexity and cost of the equipment needed.

Of course, Big Science is an advantage of a coherent community of users who enjoy the oxymoron of airline cuisine, and for that reason science policy must strive to balance between shared facilities and individual investigators.

As president and now chairman of the American Association for the Advancement of Science, I have been working hard for these past 3 years to understand and communicate the problems of all science and technology from anthropology to zoology in the Nation.

I believe we are slowly forging a unified science and engineering community, because it is only through science and technology and education that this Nation can overcome the negatives that have been commented upon by distinguished Senators—the declining quality of life, to abbreviate it all—and to achieve the positives of a far more fulfilling life for a much larger fraction of our citizens. A component of this science is the SSC.

With your permission, Mr. Chairman, I am going to set the supercollider in historical context. I think it is important to explain why this is not just another atom smasher. I want to try to lay out for you, as I have to my liberal arts freshmen at the University of Chicago, as I did to a group of 30 Federal district judges a few weeks ago, and to my wondrous 7-year-old grandchild just the other day, gentlemen, science, the process of trying to understand the world in which we live, was started in ancient Greece roughly 650 B.C.—I think it was on a Thursday—when in the Greek colony of Miletis some well-to-do businessmen sat around and decided the world could be understood by logic and that this must be—or there must be an underlying simplicity, a deep symmetry which can account for the world and all of its complexity.

The road from Miletis in 650 B.C. to Washington, D.C. in 1992 is very clearly outlined in our history. Mr. Chairman, the motivation is human curiosity. How does the universe work? How does the world work? That sentence could be written in moving lights on the marquees of all the laboratories of the world—on the famous library of Alexandria in Egypt, on the third tier of the Leaning Tower of Pisa, and on the European labs like Cambridge and Gottingen and Copenhagen, where our heritage and our teachers' teachers created the modern science we enjoy today.

How does the world work? This was the drive of Isaac Newton, who established the laws of mechanics and gravity that today is taught in all engineering schools and whose equations are programmed into NASA's computers. This was the drive of Michael Faraday, who learned enough about electricity and magnetism to electrify the world.

This was the drive of Maxwell, who understood radio and light waves, and Thomson who found the electron, and Ernest Rutherford, who found the nucleus in 1910, and Max Planck and Einstein and Heisenberg and so many others who changed the way people live on this planet, and whose pure, basic, abstract research now account for a large fraction of our $6 trillion GNP, and do not let any cynical, average scientist tell you that this sequence of striving, of understanding, of addressing the issue of how the world works has come to an end, because they cannot know.

Mr. Chairman, history and circumstances have put this house—the U.S. Senate—in charge of a continuation of a 2,500-year-old quest for comprehension of the world in which we humans find ourselves. The road from Miletis and the history of our quest for who and what we are stops at the supercollider. It is the repository of the vision and enthusiasms of a large community.

The SSC has been in the dreaming and the arguing and the debating and the planning and the designing phase for over 12 years, since 1979 when we began to be aware of obstacles to progress. In 1982, when we first conceptualized the machine we would need to address the issue, we were shocked at the huge scope of the project, but we saw no alternatives.

Why did we collectively commit to so huge an undertaking? I am here without slides, without blackboard, totally insecure in all of this, to tell you in my own way. Let me reassure you that my grandchild did get the idea, although he preferred to play Stratego.

The road from Miletis to the SSC is what philosophers call a reductionist road. The Greeks invented atoms, theoretical objects too small to see, but whose infinitely varied combinations made all the things in our rich, complex world. Atoms were first discovered experimentally by the chemists in the 19th Century, but their detailed structure was clarified in the early 1900's and understood precisely in the 1920's.

With the conquest of the atom, we zoomed down to the nucleus, and we learned, and the sequence is that molecules are made of atoms, and atoms are made of nuclei and electrons, and nuclei are made of protons and neutrons. Our strategy was to uncover the simplest elements of the structure of matter as a key to understanding and to control.

Inside protons and neutrons, quarks. This is the bread-and-butter of current research in Batavia, Illinois, and Palo Alto, California, and in Geneva, Switzerland, in Tsukuba, Japan, and in Hamburg, Germany. Now we have reached what many, a consensus, believe is the bottom line. The quarks and electrons and their friends are, we believe, points of mass and energy in space.

The quark picture is very concise and correctly accounts for all the data we have collected over the centuries. However, the underlying simplicity still eludes us. Our current world view has 12 basic point-like particles which interact and combine with each other via four forces of nature.

We know and are continuing to learn in our labs a great deal about the point-like building blocks of matter and of the nature of the forces, and like the motorist on a winding forest road, we are beginning to glimpse, however fleetingly, the towering peaks of a grand unity, but the mathematics is incomplete when we try to predict what happens at higher energy, at the energy of the supercollider, and this is a sure sign that something important is missing.

Until we can complete the unification process and make the picture mathematically whole, the question of how the world works will not be answered, but the obstacles realized in the 1970's focuses on a bizarre, revolutionary new idea which was immortalized by the mayor of a place called Waxahachee, Texas, who in public some years ago said, "we have got to find the Higgs Boson."

If the mayor of Waxahachee can say that, something is happening in this Nation. The idea for the past decade or so is no longer what is inside—what is inside—although we hope to continue to look. The Higgs idea which was so articulated by the mayor, is that we are looking at nature through a new and as yet hypothetical force field that in a sense makes a simple, overarching symmetric world look complicated.

The Higgs idea also enables us to have a mathematically consistent and unified view of the world. As a metaphor, think of a child's kaleidoscope, which exhibits patterns of beauty and complexity as you rotate the tube, but inside, if you take it apart, one sees a few bits of colored glass and an ingenious array of mirrors. Higgs is like the mirrors. The pattern of colored glass is the simple formula that would tell us how the universe works.

Another metaphor, however limited, is think of a group of extraterrestrials watching a soccer game, but somehow they are incapable of seeing the ball, and they see a lot of people running around seemingly at random in a chaotic disorganized activity, but if someone postulates the existence of a soccer ball, then the whole thing becomes clear and simple and elegant.

The SSC is specifically designed to be sure to study this new concept so briefly described, but lest you trivialize it, let me tell you that Professor Weinberg, whom I introduced a moment ago, and his colleagues won the Nobel Prize for using this concept to unify two of the four forces of nature and to show us the road, but there is more.

In a few minutes, you will hear from Professor Smoot, an astrophysicist who will talk about what we know of the birth of the universe and its evolution from an incredibly dense hot beginning to the world we now know and love, and he will tell you why the cosmologists, the outer space jocks, we call them, are just as eager for SSC data as the particle physicists, because something like this Higgs concept turns out to be essential to supervise the crucial phases of the origin of the universe.

The synergy of inner space—particle physics—and outer space—cosmology—is one of the most dramatic events in the history of science, and so that is why physicists from Fermilab in Illinois and SLAC in California and Brookhaven and Cornell in New York, disgruntled as we all are at the loss of the SSC in our own State, and fearful as we are about the long-term funding of our own institutions, are nevertheless joining together to support this project.

A huge community of mostly younger scientists from all over the country, from over 80 U.S. institutions, and institutions all over the world, have invested in this program, and let me point out that a letter written to Chairman Bennett Johnston has been signed by something like 13 Nobel Prize winners in chemistry and physics, assorted National Medalists of Science and various directors, all asking for support of the supercollider.

Let me be clear. The SSC will address the Higgs issue, of that much we are sure. In so doing, it will also address the unification problem. Without SSC clarification, the field just stops. There is no other way to proceed, at least in the United States.

Mr. Chairman, we are often asked what the SSC will do for society. My response tends to be a bit different from most colleagues. As a huge technological project at the cutting edge of technology, the construction of the machine and its experimental devices is bound to make inventions which will be commercialized and which will pay back to the Treasury in taxes some significant fraction of the cost and operating budget. Every new machine can document this, from SLAC to Brookhaven's strong focussing to Fermilab's pioneering superconducting technology.

But that would be a crazy reason for building the SSC. We do not build it for the spin-offs. We build it because we are humans who think and are insatiably curious, and have an unquenchable determination to know.

Our goal of the comprehension of the universe in its infinite glory and of mankind's ultimate fate within it is mankind's achievement, the furthest point yet reached in the progressive expansion of human intelligence and power, and if the knowledge gained from the SSC research, blended as it will be with data coming from the great accelerator in the sky, the early universe, clarifying and synthesizing as it must the research of the past 40 or so years, if this does not have a profound influence on society, and unpredictable at this stage, then it will be the first time in history.

Let me conclude with two points. One is that the state of modern industrial society is a product of our past investments. That our longevity has been extended, diseases have been conquered, the ability of citizens of very modest means to live better, more fulfilling lives than the kings and emperors of just the 19th century, that the United States is still, with all our terribly serious problems, the most prosperous of nations, is a product of the wisdom of Senators and Congressmen and Presidents to invest in this thing called science, and for this your institution deserves the greatest of respect.

The other point is that we are all aware of the dilemma facing each and every member of Congress. Our problems are numerous. Our air and water, our atmosphere, our global environment are under stress. New diseases affect us. The economy is stagnant. Our cities continue to decay, and a seemingly permanent underclass defies compassion and fairness, and our budget is in serious deficit.

It takes enormous courage to continue to invest in a program so abstract, so difficult to explain to constituents, so long-term and uncertain in its pay-offs. But think, too, that perhaps it is just because of the problems that long-term investment in science and education is needed.

We live in a time, the first time in the history of our Nation, when our children are, on average, worse off than their parents. The mood of pessimism permeates the Nation. If we turn our backs on the supercollider and in effect vote to terminate this field of research in the United States, it is one more signal, one large signal, that we are less interested in the long term.

The message will go out to the young men and women we so desperately want to recruit into science—into all science. I fear that our vitality as a once exuberant and vital society will decline, and I really do not know how I will explain this to my grandchild.

Thank you.

The CHAIRMAN. Next, we will hear from Dr. George F. Smoot III, who received his Ph.D. in physics in 1970 from MIT. His area of research is in astral physics and cosmic ray physics. He made world news this year with the discovery of ripples in the universe, believed to be the primordial seeds that grew into the present-day galaxies. He is currently at the Lawrence Berkeley Laboratory, as well as the University of California Berkeley Space Science Laboratory and the Center for Particle Astrophysics.

Dr. Smoot.

STATEMENT OF DR. GEORGE F. SMOOT III, SCIENTIST, LAWRENCE BERKELEY LABORATORY, BERKELEY, CA

Dr. SMOOT. Thank you, Mr. Chairman, you and your colleagues, for inviting me here. I am not quite as secure as Dr. Lederman, so I prefer to stand up and talk and be able to show you some pictures because I have some pretty pictures to show, but I would like to reiterate a little bit about what Dr. Lederman was saying, if I can make this work, and that is what I am going to talk about is cosmology. And in cosmology more than anywhere else you see the unity of the sciences. When you study the origin and development of the universe you actually are studying everything that is going on from the very early stages to the things you see in the present. When you do that, you find out you must know a lot of science just in order to study the universe as a whole. You learn a lot of things because you have to see everything in the universe; and the more you do it, the more you see the underlying unity of all the sciences. So when you start talking about well, should we fund medicine, should we fund this, or whatever, all those things are linked together.

On my way here, I passed through Philadelphia and there were a bunch of people on the plane that had cataracts. I wondered why they were flying them to the United States. The answer was we have laser surgery that we can do at the University of Pennsylvania with new experimental techniques for advanced cases. That is a sort of unification of medicine and science to learn how to do those kind of things. It just shows you do not know what development is going to turn out to be something useful in terms of what is going on. You really have to understand the basics of all of science. That is where physics, and particularly high energy physics, come in together because physics is what we call the queen of sciences. It is the basic underlying structure for all of sciences, the foundation everything sits on. You have to understand physics to understand what is going on.

Well, let me talk a little bit about cosmology. Cosmology is what we call the scientific approach to the origin and development of the universe. What we do is we make the assumption that we can use reason; that is, mathematics and thinking and observations, and we have very few observations about the universe—then we can use the laws of physics, the laws of science that we find from doing experiments on the earth, and from that, we can model the whole behavior of the universe.

As the chairman said, my team is famous for recently having found evidence that clinched in a lot of people's mind the idea that the universe was born in the big bang. When you go back in the universe and the history of the universe and the big bang model, as you go back you find the earlier you go the hotter and the more energetic the universe was and the smaller it was. That is what ends up being the ultimate connection between the very large; that is, our universe as a whole—and the microscopic, which is now high-energy physics, particle physics. So I want to talk about that a little bit.

But I will show you a picture that sort of relates to that before I get into telling you a little bit about cosmology, what we have learned about the universe. This is the exciting part for me because finally we have made these observations and everyone in the world sort of has seized upon it. It made headlines. It is a great opportunity to go out and talk to people about what you are doing, how it all fits together, and how, in fact, physics and cosmology and astronomy and the evolution of life on earth, all those things fit together.

This is just a monograph that shows how, in the model of the big bang, that as you go back in time you go to different energy scales and through the present time scale we are talking about things that are very cold. As we go back in time to when the universe was 1 second old, or a millionth of a second old, we get back to higher and higher energies. So here is the energy scale. This is the energy scale of everyday life processes of the sun, of what we had in early accelerators, and what we are talking about for the SSC, and that is where this dotted line goes.

What's happening is we sort of understand through our experimentation on the earth what is happening, and sort of, to my viewpoint, and that is because I am young, 20 years ago we had what was called classical cosmology. Steve Weinberg wrote this great book called, "The First 3 Minutes," that talked about what happened in the universe from about a thousandth of a second through the first few minutes of the universe, and that is where nuclear physics is important, where the light elements were made and how we came to understand that the universe probably came from a big bang. But all that is based on reason and the assumption that the laws of physics and things that we understand on earth apply to the universe as a whole, because the total number of observations we have about the universe is actually quite small.

I put them all down here so you could see them. We do not know much about the universe. In fact, we only know four things up until this most recent decision. The things that are important to us in terms of knowing about the universe as a whole, the observations we have made far away, is the sky is dark at night. We know the galaxies are receding; that is, there are galaxies outside of our own and they are receding. I will go through each of these later. The abundance of the light elements, the nucleosynthesis that we talked about, and the existence of the microwave background, and now these new results which we think were the seeds for forming all the structures that we see in the universe today. So let me talk about it a little bit.

I will now show you my first pretty picture. This was taken from one of the three instruments on the Cosmic Background Explorer satellite, and hopefully I have a handout for you. But this is a picture of what it looks like when you look out into the dark night sky. Mostly when you look out you see darkness. It is not light at night, it is quite dark. When you look out you see a few points, and those points are stars—it is typical, that is. You actually have to go and look out in the plane of the Milky Way and toward the galactic center before you see anything that is really bright.

What you see is the plane of the galaxy which is very much like the plane of the rings of Saturn. That is, when you look at the rings of Saturn from afar it looks like a solid body, but when you get up close in a satellite you find a satellite can go right through it because it is mostly just chunks of ice and they are widely separated.

Our universe is pretty much like that. There is just a few chunks of matter out in space and most of it is collected into little balls that we call stars, and those balls of stars are collected into large aggregations called galaxies. So this is the point of our galaxy which has mostly stars, and this dark material here is dust, and then there is a central bulge around the center of our galaxy. This is what it looks like from our position in the galaxy. We are actually in the galaxy but we are far out toward the edge so when we look out we mostly see darkness. It is only when we look down toward the center of the galaxy we see anything.

Well, that was a big mystery. People have known that the sky is dark at night for quite a long time. Around 1600, people started realizing that implied something about the history of the universe, but it was not until 1836 that Olbers wrote it up in a monograph that it got a name. It is called Olbers' Paradox, and that is if the universe were static; that is, it has always been the way it is now—and it is infinite—as far as you look, no matter where you look, you eventually see a star, and so the question is why is not the night sky as bright as the surface of a star, because everywhere I look is a star.

Of course, the bad thing that happened if you were a student really doing this experiment is you would get a little warm because the surface of a star is quite hot. It is just like being on the surface of our sun. So the question is: Why are we not all burned up?

Well, you can try a trick like putting a lot of dust or things in the way, but if you think about it and reason very carefully, you realize that those things, if you wait long enough, will get so hot that they will be a star themselves. So the fact that the night sky is dark is telling us that the universe is either finite in time or it is not static. So we will—or it is not infinite in extent. But every time we make the measurement we can see further out. So that is one of the things we know, that somehow the universe is not static, that it is expanding, it is moving.

In the 1920's, Hubble went and demonstrated there were actually stars outside of our star system, the Milky Way, and that those big aggregations were very large distances, and they were called galaxies. He called them nebulae, but nowadays we call them galaxies. Since then people have used big telescopes and done big sky surveys and they have found out not only is matter clumped in stars and the stars clumped in galaxies, but here is a plot of the northern sky. Each dot on here is a galaxy. If you are up close you can see an individual galaxy. If you are far away you can only see them in groups of a few to 10.

But this is what the sky looks like at the North. This is what you would see if you were looking at the North Pole. You would see a large cluster of galaxies here very near the North Pole. That is called the Coma cluster. It has about 2,000 galaxies in it. But if you look in other places you see large groups of galaxies, and these large groups are often linked together in strings or in big regions where there are not very many galaxies.

This is a two-dimensional overlay. When you start estimating the differences, you see the universe is sort of full of voids and full of big sheets and great walls of galaxies and so forth. We see structure on all scales, and so the question is: Where did those objects come from? How did that structure form? What does it look like? We have always believed that the answer is one of the four forces, gravity. We think gravity should show up in different ways.

I will show this pretty picture. This is a picture of a cluster of galaxies. It is highly exposed so that you can see behind it there are all these very faint blue galaxies. They are blue because they are brand new and they just turned on. They are very hot. But these blue galaxies sometimes appear behind big clusters. This is called Abele 2218, which is named after an astronomer who looked at rich clusters of galaxies. What you see is as the light from those distant galaxies goes by another galaxy it gets lensed. It gets bent. That is, space/time itself is bent by material in it. And that light going by these galaxies is bent, something that Einstein predicted, tells us about the structure of space and how it is related to the material in it, and how much material there is in it.

What you can see is these faint blue galaxies, when they get near this cluster of galaxies, they get turned into arches. You can think about it this way: Suppose you have a very different galaxy or quasar and you have a galaxy in the line of sight between you. The light from that galaxy or the distant quasar is bent. If it is perfectly in line you will see a ring—it is called an Einstein ring—of light that is bent around it. Here you see some of the images, some of the ring showing out. But measuring that, you can measure how much material there is in here. We keep finding that the light material is not enough material to explain everything we see, that there is some dark matter missing. So we wonder what that is and we have been trying to study that, and that is one of the questions that the SSC will get to, and I will talk about that later on.

The third piece of evidence we have in terms of the big bang is we look out at the old stars. The smaller a star is the more slowly it burns. That is because if you have a big star its gravity compresses it and makes it hotter and its reactions go fast. If you look at very small stars, you can look at the material in it and you find out that it is mostly made of very light elements. And the question is: What is the cause of that? The answer is we can find that out from nuclear physics, things that we knew in the 1940's and the 1990's.

If you start with a universe that is made of soup, of protons and neutrons, and you just let those protons and neutrons interact, eventually two will come together, a proton and neutron will come together, and you will get deuterium. Then, if a deuterium atom nuclei happens to run into another neutron you will get helium-3—I mean, sorry, tritium, and if the tritium runs into a proton you will eventually get helium-4, and you can continue that process for a little while.

But when you try and get up to beryllium-8 you find that it is not stable because the photons that are around to heat this, necessary to make the early reactions go, blow that apart. So you can make up all the light elements and it explains why all the raw material in the universe is essentially three-quarters hydrogen and one-quarter helium and just a smattering of other elements.

We understand that process. What it does do is predict that there should be a relic thermal radiation from that early time. In order for the reactions to go, the early universe had to be hot, and it had to be hot like a star so that nuclear reactions should be occurring. So there is some prediction that there should be a cosmic microwave background, a relic thermal radiation from the early universe.

In 1965, Penzius and Wilson, who were working at Bell Labs on satellite communications, the Echo satellite had been recently launched and they were wondering well, can we do telecommunications? That is, can we have a satellite phone call system, the thing that we use all the time now. Can we do that? What are the radio backgrounds in the sky? They went out and measured very carefully what the temperature of the night sky was in terms of noise and heat and power coming in. They found in 1965 that there was a background radiation, and it is a radiation that is coming in from all directions. It turns out it has a thermal spectrum, and that is one of the things we measured on the COBE satellite.

Let me show you that more precisely. As science has gone on we have made some more progress. The dots on this curve are the data, including estimated errors in it, and the smooth curve is the prediction of what a thermal spectrum should look like. As you can see, this looks pretty good. If a student did this in a lab we would say he cheated. But I can tell you this is real data. So with these, the big bang was on really firm footing, but we had started out this satellite project to do three things. One was to measure the spectrum to see if it was thermal. The other is to measure what its angular variations are, looking to see if we can see the primordial seeds in the universe. The third one, which we have not reported our results from yet, is to look for the light for the first generation of stars and galaxies that are out there so we can really think we are understanding what is going on in the universe.

Well, it has been a long project. There are a lot of people involved. There were originally six of us who proposed the experiment, but over the time period we brought in a lot of managers and a lot of engineers and technicians and other scientists to help us and programs to do it.

Here is what the satellite looked like 3 years ago when we were readying it for launch. It was launched on an expendable rocket, so we had to make the thing small in order to fit in there.

This is a shield which I will show you expands that goes around the instrument package. This is the thermal control and the solar cells that go around the center part of the satellite which controls what is going on. This is the booster ring, mounted on the top of the rocket.

Here are some of the technicians that are finalizing locking some of the solar panels into place. This gives you some idea of the scale of the experiment. It weighed about 2½ tons when it was launched.

Here is a schematic of what the satellite looked like when it was in orbit. Now you can see all the various things deployed. Here is the satellite module. In the satellite module there are three solar panels that are exposed, one hidden from view there. The solar panels provide the power. The communication antennas provide the link to get the data to the ground and the commands up to the experiment. There is thermal control and, most importantly, attitude control; that is, the pointing. We had to go into a particular orbit. It was an orbit which is on the night-day line on the earth. That is so we could look away from the earth all the time and be in a situation where the sun was shining on the satellite all the time but not on the instruments. So in order to do that, we had the sun shining in from this side, we rotate the spacecraft to keep it smooth, but here we have the instruments inside a shield in order to protect them very well.

Now it is time to show you what we did with the instruments, but first I have to orient you. So here is an experiment that people did doing the opposite. The same kind of technology that we use for looking at the universe has been used for looking at the earth, also. This shows you something about the unity of science and technology, that almost exactly the same technology is used to look down and to do earth resource surveys. So here is the opposite experiment. Instead of looking up, now we are looking down at the earth and we are measuring the average temperature.

Now, the problem is the earth is a sphere and so I have to show you a map of the whole earth on a flat piece of paper, so I take this oval shape, so if you will look here you can do an inventory. All the earth is shown here, North and South America, Europe, Africa, Asia, Australia, North and South Poles. They are all shown on here, and I can show you the mean temperature of the earth as a function of where you are looking on the earth. You will notice that the variation is actually quite large on the earth. It is on the order of 20 percent across the surface of the earth. I will show you pictures of the sky that are much different than that.

I am going to show you in the same coordinate system but looking the other way now, looking out from the earth, out at the universe, to show what the temperatures of the universe look like. Now, when you make the observations at short wavelengths you get a picture of the sky that is very different than what you get looking at the wavelengths where we make our own emissions. This is the picture I showed you before, the whole sky. You can see, basically, most of the sky is empty. Just the part where the galaxy is and just a few stars near us are showing up. This one shows up. If you do the same observations in the optical but use a very large telescope in order to make these observations, you see just a few more points of light but the same basic picture.

This is essentially all the stars that you can see in the sky with your eye plus 10 times as many that you can see with a telescope. Basically, you see the plane of the galaxy. The center of the galaxy is here. Now, when you look in the optical you cannot see through the dust very well. And so the dust blanks out a large part of the sky. When you look through the infrared you can see through a lot of that pollution. But mostly, you see that if you look away from the plane of the galaxy you do not see very much.

If you go and look at longer wavelengths you see pretty much the same picture, but if you look right at the wavelength which is approximately the size of your finger you see a picture that took us 15 years of my life and millions of dollars of the taxpayers' money. This is what you see. I hope you are impressed with what you got.

This is in the same coordinate system. The center of the galaxy is here and the plane of the galaxy runs across that.

You can see, when you look at a wavelength which is about a quarter of an inch to an inch, the sky is pretty different than it is anywhere else. It is very uniform. In fact, if you take away the average value of the sky in order to see any feature, you have to look a thousand times more sensitively, and when you do, this is what you see.

We call this the dipole; that is, there are two places, one pole that is warm here in the sky, and if you go smoothly across to the other side one part that is cool. Now, by warm and cool I do not mean very much. I mean it is one part in a thousand of 3 degrees from absolute zero, or three-thousandths of a degree is the variation across the sky. Now, you can see just the basic hint of the galaxy showing up. Here is the center of the galaxy. Looking down one spiral arm right here where you see a bunch of sources superimposed. Over on this side there is another spiral arm which is sort of hidden in the red spot. You cannot quite see it.

Now, we think this dipole anticentropy is caused by our motion. That is, in the direction we are going we are catching more light from the early universe and the direction we are leaving we are getting less. It is just like driving in your car. There is more rain on your front windshield than on the back windshield, and that is what we see. So the universe as a whole is very uniform, and even when we see the first variation in it it turns out it is not because the universe is nonuniform, it is because we are moving. If we go and say let us go into a coordinate system where we are not moving and correct for that, then what do we see on the sky?

Well, we have to take and expand the scale another factor of 10, and this is what we see finally. This is what all our excitement was about, that this part is the plane of the galaxy again, with the galactic center here, the spiral arms, it saturates the picture here. But if you look away from the galaxy, now, instead of seeing a few points of light like we used to, now we see huge regions that are cold or hot, varying around here, and they vary on all different scales on the sky. We see them from the smallest scale that we can get to the very biggest scale we can look at, and it is very much like the picture of galaxies I showed you, that stars are made and the stars clump into galaxies and the galaxies clump in clusters and the clusters clump in clusters of clusters or in great walls or sheets or strings or big voids or so forth.

That is pretty much what we are seeing here. Back when the universe was very young—that is, about 300,000 years out of the 15-billion-year total lifetime—we see variations. Now, these variations, they look pretty dramatic on this map, but they are only variations at about a part in 100,000. We need the full 15 billion in order to make the structures that we see today, and in fact, that is really not quite enough. We need, in fact, some new kind of matter, which we call dark matter for historical reasons, but a better name for it would be invisible matter; that is, matter that does not interact with light.

The way we see it is just like you would see the invisible man. When he walks across the carpet he squashes the carpet a little bit or he walks across the grass he squashes the grass; by looking at how much deflection there is we can tell how big the invisible man is, and that is pretty much what we are doing here.

So we can do that. We can also model out the galaxy and look and see what we can see in terms of the early universe. This is our best estimate of what we call the baby photo of the universe. If the universe was middle aged today, this would be a picture of what the universe looked like when it was 5 years old. So it really is a baby photo of what the universe looks like. Here you see the variations, spots that are hot and cold, spots that are going to grow into the structures that we see today. And in fact, some of the structures are so big they have not had time to form yet. They will be forming after the universe is twice as old as it is now; in its advanced senior citizen stage, or—I have forgotten your official term—chronologically advanced time.

So what we have has given us a lot of confidence that we understand what is going on because we needed to see these variations in the early universe. We needed to see them to make sure we could understand how structure formed in the universe, that there was this big bang, that everything was hot and close together, and that there were these small variations and these small variations grew to the structure we see today and newer structure is going to be forming.

Now, it gives us a lot of confidence in the model and we can go forward. We can understand what is going on in the universe. We have a sort of a schematic. Here is the whole history of the universe from a tiny fraction of a second to the present day. Something went on in the very early universe—we do not know what it is—but there was a lot of chaos. Then we go through this period which we hope the SSC will help tell us about which we call inflation, but it is where space time itself is really formed and what we are going to build today comes into being. Then we make this transition where matter and antimatter come out of balance and matter is left over, matter has mass, and that these variations then continue on to be the stuff that we see today.

We hope, in fact, the satellite will soon actually be telling us about what we call in this picture the zone of mystery. We have been probing into this region and into this region. We want to know what is going on in the galaxy formation region. We hope our third instrument is going to tell us something about that. But what we are here to talk about today is what does this tell us about the early universe? I remind you of this original plot. As Leon Lederman told you, we have probed with our science back to about this stage. Weinberg and his colleagues got the Nobel Prize for unifying weak and electromagnetic interactions. We know there are at least two other forces in the universe, the strong interactions that have to do with the nuclear forces, and gravity, which we think are going to be unified in some way. But with the SSC we are going to be investigating this part of the region, back at the tenth of a billionth of a second to a thousandth of a billionth of a second in the history of the universe. We really want to be probing way back in the universe to find out what was going on.

There are three critical questions that we want to try and answer, and this is my final summary before we let Roy talk about how we are going to do it, and that is the higher the energy you probe the earlier in the universe you look. By now, the SSC is the frontier. It is the next logical step in terms of going to higher energy over what we have now, and it is the only source in the world of what is going on to do that.

The thing about the SSC, the reason it was so big and such a great step, is that, as Leon said, people sat down and figured what did we have to do to get to the physics we need to know. Well, the first thing we needed to find out about is what is the origin of mass. In the early universe, we have now found out that the protons were made up of quarks and gluons and so forth. How do those things acquire their net mass? Why did they become substantial instead of being flimsy and lightweight or no weight at all? Then the question of why is there an excess of matter over antimatter, you know, how we came into being? We know that in the early universe there was almost exactly equal parts of matter and antimatter. There should have been an equal amount. How did it turn out that we have a slight excess?

Finally, something that cosmology has pushed into particle physics, the question of what is this dark matter? What is the nature of it? We know it is probably not ordinary matter. It is some kind of weakly interacting matter which is going to come from the SSC scale.

So if we are going to continue pushing the frontier to understand the basics of science, we are going to need the SSC in order to answer some of these questions and tell us what is going on.

Thank you for giving me the opportunity to share this with you.

[The prepared statement of Dr. Smoot follows:]

Prepared Statement of Dr. George F. Smoot III, Scientist, Lawrence Berkeley Laboratory, Berkeley, CA

Cosmology, the scientific study of the origin of the universe, assumes that the laws which govern the behaviour of the universe as a whole are the same laws of physics that are discovered by experimentation here on earth. Cosmology simply cannot progress without advances in our understanding of the basic laws of physics. The most important force at large cosmological distances is the force of gravity. Modern cosmology could only be born after Einstein developed his theory of gravity, General Relativity, in 1916. The theory of quantum mechanics, developed in the early decades of this century to understand the physics of the atom, was crucial in allowing progress in cosmology. It allowed Hubble to use his observations of distant galaxies to infer that the universe was expanding, and from observations of diffuse microwave radiation one could infer that the universe was once very hot.

How has the universe come to its present state? This is the central question of cosmology. Imagine starting with the expanding universe we see today and running it backwards in time. The galaxies which are now far apart would get closer and eventually merge and then get compressed. This compression causes the universe to get hotter; eventually the atoms break up into a gas of elementary particles. This is the hot big bang picture of the early universe. The most important cosmological questions have answers which have to do with the particle collisions and processes which are occurring at very early times in this hot gas. The earlier the time the hotter the gas, and the more energetic are the collisions between the particles. This is the deep connection between particle physics and cosmology. The cosmological questions cannot be answered until the particle physics at the relevant energy is understood.

Why are the abundances of various different types of particles in the universe what they are? This is a very basic question since it largely determines what the universe looks like. We already have a partial answer to this thanks to our understanding of nuclear physics. One makes a primordial broth of protons and neutrons and lets it cook according to nuclear physics and soon gets the light elements. The abundances of the light elements, such as deuterium, helium and lithium, can be calculated because we know that these elements can be made in a sequence of reactions which starts with proton-neutron collisions, and the rates for these reactions have been measured at accelerators. These calculations agree well with observations and provide strong support for the big bang theory.

The early universe had to be hot for the nuclear reactions to occur. Thus the original calculations by Gamow and his students Alpher and Hermann predicted that the big bang must have been hot and that a relic thermal radiation would remain. The standard cosmological model, the hot big bang, was established in 1965 with the discovery of the thermal relic radiation by Penzias and Wilson, working on satellite radio receiver technology at Bell Labs. The FS instrument on the COBE satellite has measured this radiation and shown quite precisely that it is of thermal origin.

This classical big bang model provided cosmologists with a theoretical framework for describing the development of the universe from a time of about one hundredth of a second to the present. To go to earlier times required understanding physics at higher energies (temperatures). The experimental and theoretical development of the Standard Model of strong and electroweak particle interactions and ideas about grand unification provided a context and motivation for extending and expanding the original Big Bang model. High energy physicists found that protons and neutrons were composed of fundamental particles (quarks and leptons) which are pointlike with asymptotic freedom from strong interactions at high energies. This provides a picture of the early universe as a dilute gas of weakly interacting point particles. (quarks, leptons, and gauge bosons). This picture is more readily understandable than the old view of the epoch before 10^{-5} sec, when particles were crowded together with separations less than a typical particle size (e.g. a proton). Within this context it has been possible to develop a scenario of the universe from very early times (10^{-35} sec) including a phase transition induced period to make a clean, flat space-time, the excess of matter over antimattter (baryogenesis), and other events treated as initial conditions in the original big bang model (e.g., the fluctuations that lead to formation of galaxies and other structures). At this point we are ready to pursue this idea scientifically but need data to proceed.

To go further one must be able to calculate the abundances of the protons and neutrons. What is the origin of the basic building blocks of all known matter in the universe? We do not know the answer to this question. We believe that somehow these protons and neutrons had their origin in particle collisions at much earlier times, and therefore at much higher energies, than those which created deuterium and helium. Nobody has succeeded in calculating how many protons and neutrons would have been made in these collisions because the relevant high energy particle processes have yet to be discovered at accelerators.

The energy scale to be studied at the Superconducting Super Collider (SSC) is the current forefront energy of high energy physics. It is a crucial energy regime since it is here that the fundamental theory of the origin of elementary particle masses lies. We do not know what this theory is. Perhaps it will involve new particles, such as the Higgs boson. Perhaps new strong forces will be discovered. Whatever the theory the SSC will be at the right energy to investigate it. At very high energies there were equal amounts of matter and antimatter. Something created a slight excess of matter over antimatter to produce the observed universe composed almost entirely of matter today. Theorists already know that particle collisions at the SSC energy level have all the ingredients necessary to produce the excess of matter. It is our expectation that the SSC will uncover the mechanisms underlying the origin of mass and matter in the universe.

Strong experimental evidence suggests that the observed material in galaxies accounts for only a fraction of the total mass in the universe. There is also evidence that much of the unobserved dark matter is made of new types of particles that have never been made in the laboratory. Discovering such particles would revolutionize particle physics. The big questions are: What will their mass be and how will they be discovered? The theory of the big bang constrains their mass below about 100 TeV (100 million proton masses). One possibility is that the mass of these particles originates in the same manner as the mass of all the known elementary particles. If this is correct, the SSC offers a bright prospect for discovering this new world of particles. Once the nature and properties of these dark-matter particles have been studied, we will really understand for the first time what the contents of the universe are, and this will lead to much more reliable theories of how galaxies were formed from the cooling, expanding gas of the early universe.

We wonder what in the universe is an accident and what is fundamental to the design. For example, it is fundamental that the earth is round and that there are mountains; however, the exact height and location of Mt. Everest is an accident. This is not so obvious standing at the base of Mt. Everest. Particle physics lets us make use of fragmentary observations of the early universe, while cosmology provides a glimpse of interactions at ultrahigh energies and exotic conditions. So far we have found that using reason (mathematics), experimental tests on earth, and observations we have made remarkable progress. Things we thought we would have to take as given may now be naturally explained, e.g. the flatness and isotropy of the space-time and the origin of large scale structure, may also automatically come from the unification of the basic physical forces. We have great optimism from the early successes of the classical big bang model and the new COBE DMR instrument measurements of small-amplitude but large physical scale fluctuations in the early universe. The natural explanation of these results lies in the microcosm and energies of particle physics. The very early universe was unimaginably small where the extreme high energies and forces combined to make not only space itself but essentially everything in it including the material and the primordial seeds of structure in the universe. The SSC will let us probe the physics of the universe back towards its very beginning.

The discoveries that will be made at the SSC could have far-reaching consequences for our understanding of the universe. Although such cosmological advances cannot be guaranteed, it is certain that they will not be made if particle physics at the SSC energy scale remains unexplored. Cosmology and astrophysics must continue to walk hand-in-hand with particle physics. Science is not a collection of discrete disciplines, but a seamless fabric. This unity is seen in the deep connection between particle physics and cosmology emerging from our efforts, experimental and theoretical, to understand the beginning of time.

LAWRENCE BERKELEY LABORATORY,
Berkeley, CA, June 1, 1992.

Hon. JAMES D. WATKINS,
Secretary, Department of Energy, Washington, DC.

DEAR ADMIRAL WATKINS: I was very pleased by the interest you expressed in the COBE satellite results on the Big Bang when we spoke during your visit to the Lawrence Berkeley Laboratory last week. Your enthusiasm and excitement about our new understanding of the creation and evolution of the universe were heartening. The great public interest that the COBE results have generated shows that scientific curiosity is shared by people everywhere. The Department of Energy has contributed importantly to this new understanding through its support of fundamental science—high energy and nuclear physics in particular—as well as technology and instrumentation.

It is through such support for basic research that we were able to take this historic step toward solving the age-old mystery of how the universe began. The answer can be found only by linking two great sciences, the science of the incredibly large (astrophysics and cosmology) and the science of the incredibly small (particle physics and quantum gravity). This connection arises naturally because cosmology is based on the assumption that the laws governing the behavior of the universe as a whole are the same laws of physics revealed by experimentation here on earth. Cosmology simply cannot progress without advances in our understanding of the basic laws of physics.

How did the universe begin? Until a decade ago we had only a sketchy answer. Beginning with the Big Bang, everything was unimaginably hot and dense. In time, nuclear reactions occurred that generated the light elements like hydrogen and helium. As the universe expanded, it cooled. Once it was cool enough for neutral atoms to form, the universe became transparent to light, and the light present then persists to this day as the cosmic microwave background radiation.

How has the universe come to its present state? This is the central question of cosmology. Imagine starting with the expanding universe we see today and running it backwards in time. The galaxies which are now far apart would get closer and eventually merge and then get compressed. This compression causes the universe to get hotter; eventually the atoms break up into a gas of elementary particles. This is the hot Big Bang picture of the early universe. The most important cosmological questions have to do with the particle collisions and processes that occurred at very early times in this hot gas. The earlier the time, the hotter the gas, and the more energetic were the particle collisions.

Here lies the deep connection between particle physics and cosmology. The cosmological questions cannot be answered until the particle physics at the relevant high energy is understood.

The energy scale to be studied at the Superconducting Super Collider (SSC) is the current forefront energy of high energy physics. It is a crucial energy regime since it is here that the fundamental theory of the origin of elementary particle masses lies. We do not know what this theory is. Perhaps it will involve new particles, such as the Higgs-boson. Perhaps new strong forces will be discovered. At very high energies there were equal amounts of matter and antimatter. Something created a slight excess of matter over antimatter to produce the observed universe composed almost entirely of matter today. Theorists already know that particle collisions at the SSC energy level have all the ingredients necessary to produce the excess of matter. It is our expectation that the SSC will uncover the mechanisms underlying the origin of mass and matter in the universe.

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The discoveries that will be made at the SSC could have far-reaching consequences for our understanding of the universe. Although such cosmological advances cannot be guaranteed, it is certain that they will not be made if particle physics at the SSC energy scale remains unexplored. Cosmology and astrophysics must continue to walk hand-in-hand with particle physics. Science is not a collection of discrete disciplines, but a seamless fabric. This unity is seen in the deep connection between particle physics and cosmology emerging from our efforts, experimental and theoretical, to understand the beginning of time.

Sincerely,

GEORGE F. SMOOT.

The CHAIRMAN. Thank you very much, Dr. Smoot.

Next, we will hear from Dr. Roy Schwitters, who received his Ph.D. in physics in 1971 from MIT. From 1979 to 1989, he was a professor of physics at Harvard University and was program co-spokesman and head of the construction of the CDF detector at Fermilab. Dr. Schwitters is currently the director of the SSC Laboratory.

Dr. Schwitters.

STATEMENT OF DR. ROY F. SCHWITTERS, DIRECTOR, SUPERCONDUCTING SUPER COLLIDER LABORATORY, DALLAS, TX

Dr. SCHWITTERS. Thank you very much, Mr. Chairman.

Now, it is my welcome turn to bring you up to date on the actual progress, if you will, the nuts and bolts of the SSC project, itself. After many years of planning and design, actual construction of the SSC has begun. And this marvelous instrument and laboratory that will use it are beginning to take definite shape. Let me say at the outset that our project milestones are being met. The SSC can be completed within budget and its scientific programs can begin on schedule in time for the next century, as long as the necessary support continues to be available.

One of the first tasks undertaken after the SSC laboratory was created in early 1989 was to prepare a detailed cost estimate to plan a schedule that would permit the efficient construction of the accelerator, the experiments, and the laboratory. Other cost estimates, the ones referred to by Senator Bumpers, had been made much earlier, but they were always hampered by the fact that the designs were conceptual and incomplete and a site for the accelerator had not yet been chosen.

As the laboratory assembled its staff in early 1989—and the staff, I would say, is an amalgam of really bright young physicists and engineers; older, more experienced accelerator designers and builders; managers with experience in large and complex projects—this group, the conceptual design was adapted to the chosen site in Texas, and a careful cost assessment could be made.

In addition, we had new information about the properties of accelerators and their magnets, and we made some more conservative design choices to ensure that this machine would work as necessary to do the science, and that the critical magnet systems would be very robust.

Anyway, this baseline cost estimate and schedule was completed by the laboratory staff and then reviewed several times by independent groups from the Department of Energy. In early 1991 the Department sent to the Congress the results of that time-consuming, exhaustive effort. The Department stated, and the laboratory fully concurs, that the SSC could be completed by the end of fiscal year 1999 at a cost of $8.249 billion. I would like to tell you now how we are doing on that program.

At the SSC Laboratory, we measure progress on the project by reviewing regularly how closely our actual work adheres to the baseline schedule and budget. As might be expected on such a large project and very complex project, some individual tasks cost more than planned while others cost less, but in summary I can report this: after a little more than 3 years of work and the expenditure of about a billion dollars, the SSC project is on time and on budget. It is still early in the life of the project, but we have begun to build and to let industrial contracts, and this has given us a firm idea of the cost trends. Those trends give us every confidence that the project can be completed within the $8.249 billion budget.

From the outset, one of the major technological challenges confronting the project was the design and construction of the more than 8,000 large, superconducting magnets that will guide the protons around the 54-mile tunnel of the collider rings. These magnets are larger and more powerful than any that had yet been built. Could the design and assembly of these enormous magnets actually be accomplished?

We now have an answer to that question and it is an emphatic yes. At Fermilab in Illinois and at Brookhaven National Laboratory in New York, 12 full-length magnets of our final design have been built and tested both by laboratory staff members and by employees of our industrial contractors at General Dynamics and Westinghouse. The test results are extremely good. All the magnets have performed superbly and have even demonstrated a comfortable margin above the intended operating current.

I am pleased to report to you that last weekend we began to cool down the string of these magnets, over a hundred yards long, of these superconducting magnets. And this is a very important milestone that is being reached well ahead of schedule. I might just say that the temperature that we cooled these down to is essentially the same as what George Smoot sees when he looks out at the night sky. We cool them down to about 4 degrees above absolute zero.

The challenge now has changed from the designing and building of the magnets to developing the means to mass produce them reliably and as inexpensively as possible. The industrial contractors are currently designing and procuring the tooling that will make the mass production possible. Our experience to date with the magnet production process, the cost of tooling, and the cost of materials—such as the superconducting cable—demonstrates the accuracy of the baseline cost estimate, and the magnets will be—the system of the magnets will be the single most expensive single part of the entire SSC project.

The collider rings lie below ground at an average depth of about 150 feet. One of the major determinants of the site selection process for the SSC was the nature of the underground geology. Much of the tunnel lies in a formation called Austin Chalk, a material that is soft enough to permit rapid tunneling yet strong enough to retain its shape after tunneling without extra support.

We have completed one 265 foot deep, 16 foot diameter exploratory shaft on the site. In fact, it is quite an invention. The man who came up with this used a converted off-shore drilling rig and it is essentially like a big brace and bit and he can simply drill down a 16 or even 21 foot diameter hole in the ground. It is a very impressive adaptation of that technology.

This exploratory shaft was completed within the baseline estimate of its cost, and since that time we have built another one and started a third. A very large magnet delivery shaft is nearing completion at the site. The first three tunneling contracts have now been let, and the cost of construction of the first 13.5 miles of tunnel covered by those contracts was in our original estimate placed at about $86.1 million, but the contracts that we have already let total only $67.4 million.

So we are seeing a very favorable economic climate for the civil construction, and the basic, as I say, cost estimates are even very conservative for the tunneling. The tunneling, I might say, is the largest portion of the civil construction part of the entire project.

Experience with other parts of what we call the conventional construction—that is buildings, utilities, and beyond the tunnel—is also encouraging. We have completed—and I show you on the photograph over there where much of the construction is taking place—we have completed a very large magnet development laboratory building, shown there.

The enclosure for the string test of magnets that I mentioned, that is a surface building about 200 yards long which is now filled about halfway down the length with the magnets I described, has the same curvature as the tunnel itself.

The other buildings you see there house the critical refrigerators and cryogenics systems that are necessary to cool down the magnets. Just under construction, in fact now nearly completed, is a magnet test laboratory and other facilities.

I will show you one more photograph, underneath that, to show you what is inside the string test tunnel so you get a sense of the scale, in fact what the SSC will look like eventually. As we said, inside that tunnel we have mounted the superconducting magnets.

You can see their final orientation that they will have in the tunnel, one ring above the other.

At the present time the bottom magnet you see there is actually connected to four more counterparts and the other essential components that make up the simplest reproducible system that we carry around the full 54 mile ring. As I said, just last weekend we began to cool that down.

Now that is, again, the main construction activities going on at the site now. But in addition, the worldwide scientific community has demonstrated and continues to demonstrate its interest in and commitment to the SSC. More than 1,600 scientists have joined into two large international collaborations—in fact their spokesmen are here today—that are designing and will build the huge detectors that will analyze the results of the proton collisions at the SSC.

The collaborations already involve more than one-half of the high energy physics community in the United States, and this involves scientists at our universities as well as at our national laboratories. A comparable number of foreign scientists and their governments are investing significant amounts of time, effort, and money in planning these colossal experiments.

Careful review of the design and cost of these detectors is underway at the laboratory right now. I want to emphasize that the experimental program at the SSC, as at other high energy physics laboratories throughout the world, is driven by the interest and involvement of an international scientific community. That community is already turning to the SSC because of its promise of enabling the next major step in our understanding of the basic constituents of matter and the forces that govern them.

A unique strength of the SSC is the partnership between the State of Texas and the Federal Government. Texas has issued $500 million in bonds of the $1 billion committed to the SSC. The State has committed $227 million of these bonds to construction and other activities on the project. For example, something like $28 million of the State's funds has been used to support research related to the SSC all around the country, at our universities around the country.

In addition to its $1 billion commitment, Texas has acquired nearly 10,000 of the 16,722 acres that will needed for the super collider site. Land acquisition, which has been keeping pace with the project schedule, is expected to be completed in 1993.

As I have often stated, the SSC has two major goals: to create the world's premier high energy physics laboratory and to serve as a national education resource. During 1992, more than 20,000 students, educators, and members of the general public will participate directly in the education activities of the SSC laboratory.

Earlier this month, the University of Texas Southwestern Medical Center in Dallas announced that they will build a cancer treatment facility adjacent to the SSC's linear accelerator. Doctors will use excess protons produced by the SSC's linear accelerator to destroy cancerous tumors, an example of a benefit from the SSC that will be realized even before completion of the full project.

In the flurry of activity at the SSC, it is all too easy to overlook perhaps our most important accomplishment: the creation of a team of dedicated and talented individuals committed to exploring the unknown, to devoting a portion of their careers to creating, literally from green fields, a great instrument and a great laboratory. In my view, this laboratory has brought together the finest group of academic scientists, industrial technologists, and laboratory researchers ever assembled since the Manhattan project and the development of radar during World War II.

The United States has often been accused by other countries of being unable to carry long and difficult projectors to completion, of being an unreliable partner in international scientific and technical endeavors. Well, we are not unable to complete the SSC.

The outstanding team of men and women from all walks of life who are gathered together at the SSC and in the industrial concerns that are participating with us in the SSC are demonstrating on a daily basis that they can meet the challenges inherent in a project like this. If, in fact, we are prevented from completing the SSC, we will throw away not only the material and money already expended, but we will have wasted the physical, intellectual, and emotional investment of this exceptional team.

Over the past decade, as you have heard from Leon, the scientific community has recognized that the SSC is required to advance high energy physics. Over the past 5 years, the U.S. Government has invested more than a billion dollars in the superconducting super collider. Over the past 3 years, the SSC laboratory and DOE have been able, through strong management and clearly defined priorities, to keep the project within the baseline cost estimate.

Underfunding the SSC each year clearly puts this remarkable track record, along with its estimated cost, in jeopardy. A shortfall in 1993 funding will have definite consequences for our ability to reach the 1999 completion date on schedule. It will also increase the final cost, hurt our attempts to secure foreign participation, and slow research being conducted by scientific teams in more than 100 universities across the country.

I believe strongly that a great nation, if it is to remain great, must undertake and complete projects like this. I hope the Senate will show the needed foresight to restore funding for the project at the level requested by the President. It would allow the SSC to continue on time and on budget and help to assure that this great scientific instrument makes its unique contribution to the search for the answers to our most basic questions about how the world works. Thank you.

[The prepared statement of Dr. Schwitters follows:]

PREPARED STATEMENT OF DR. ROY F. SCHWITTERS, DIRECTOR, SUPERCONDUCTING SUPER COLLIDER LABORATORY, DALLAS, TX

Now it is my welcome turn to bring you up to date on the actual progress, if you will, the nuts and bolts, of the SSC project itself. After many years of planning and design, actual construction of the SSC has begun; and this marvelous instrument and the laboratory that will use it are beginning to take definite shape. Let me say at the outset that our project milestones are being met, the SSC can be completed within budget, and its scientific programs can begin on schedule as long as the necessary support continues to be available.

One of the first tasks undertaken after SSC Laboratory was created in early 1989 was to prepare a detailed cost estimate and to plan a schedule that would permit the efficient construction of the accelerator, the experiments, and the laboratory. Other cost estimates had been made earlier, but they were always hampered by the fact that the designs were conceptual and incomplete and a site for the accelerator had not yet been chosen. As the Laboratory assembled its staff—an amalgam of bright young physicists and engineers, older and more experienced accelerator designers and builders, managers with experience on large and complex projects—the conceptual design was adapted to the chosen site and a careful cost assessment could be made. This baseline cost and schedule estimate was completed by the Laboratory staff and then reviewed several times by independent groups from the Department of Energy. In early 1991, the Department of Energy sent to the Congress the results of that time-consuming, exhaustive effort. The Department stated, and the laboratory concurred, that the SSC could be completed by the end of fiscal year 1999 at a cost of $8.249 billion.

At the SSC Laboratory, we measure progress on the project by reviewing regularly how closely our actual work adheres to the baseline schedule and budget. As might be expected on such a large and complex project, some individual tasks cost more than was planned while others cost less, but in summary, I can report this: after a little more than 3 years of work and the expenditure of about $1 billion, the SSC project is on time and on budget. It is still early in the life of the project, but we have begun to build and to let industrial contracts, and this has given us a firm idea of cost trends. Those trends give us every confidence that the project can be completed within the $8.249 billion budget.

From the outset, one of the major technological challenges confronting the project was the design and construction of the more than 8,000 large, superconducting magnets that will guide the protons around the 54-mile-long collider rings. Although magnets of a similar design had been employed successfully at the Tevatron at Fermilab and were built in Europe for use in the HERA accelerator in Hamburg, the SSC magnets are larger and more powerful than any that had yet been built. Could the design and assembly of these enormous magnets actually be accomplished? We now have an answer to that question and it is an emphatic "yes!" At Fermilab in Illinois and at Brookhaven National Laboratory in New York, 12 full length magnets have been built and tested both by Laboratory staff members and by employees of our industrial contractors at General Dynamics and Westinghouse. The tests results are extremely good; all the magnets have performed superbly and have even demonstrated a comfortable margin above the needed operating current. Five of the industrially assembled magnets (together with other technical components) have been connected in a "string" at a facility on the SSC site. They will be used in an Accelerator System String Test this summer that will examine the performance of interconnected magnets and associated components, such as the cryogenic system that will cool the magnets to superconducting temperatures. I am pleased to report to you that last weekend, we began to cool down the string, a very important milestone reached well ahead of schedule. The challenge now has changed from designing and building the magnets to developing the means to mass produce them reliably and as inexpensively as possible. The industrial contractors are currently designing and procuring the tooling that will make the mass production possible. Our experience to date with the magnets production process, the cost of tooling, and the cost of materials—such as the superconducting cable—demonstrates the accuracy of the baseline cost estimate. And the magnets will be the most expensive single part of the SSC.

The collider rings lie below ground at an average depth of about 150 feet. One of the major determinants of the site selection process for the SSC was the nature of the underground geology. Much of the tunnel lies in a formation called Austin Chalk, a material that is soft enough to permit rapid tunneling yet strong enough to retain its shape after tunnelling without extra support. Because knowledge of the underground geology was imperfect when the baseline cost estimate was prepared, it is reasonable to keep reexamining that estimate. We are now beginning to get firm information against which to measure the estimate: we have completed one 265-foot-deep, 16-foot-diameter exploratory shaft on the site. The shaft has been carefully instrumented to allow collection of detailed information about the behavior of the underground material at the site. Results so far verify the excellent structural characteristics of the chalk and confirm that those parts of the tunnel that will go through other geological formations can be constructed using standard engineering techniques. The exploratory shaft was completed within the baseline estimate of its cost. A large magnet delivery shaft is nearing completion at the site. This elliptical shaft (60 feet by 30 feet) is also being completed within budget. The first three tunneling contracts have now been let; cost of construction of the 13.5 miles of tunnel covered by those contracts was estimated at $86.1 million, but the contracts total only $67.4 million. The winning bids were not anomalously low either; a large number of the bids received were considerably below the baseline cost estimate.

Experience with other parts of what we call the conventional construction part of the project—that is the tunnels, buildings, and utilities—is also encouraging. We have completed a large Magnet Development Laboratory building, the enclosure for the string test, and the buildings that house the cryogenic refrigerators and compressors; and we are well along in construction of a Magnet Test Laboratory. We've even completed some of the best roads in Ellis County!

The world scientist community has demonstrated and continues to demonstrate its interest in and commitment to the SSC; more than 1600 scientists have joined the two large, international collaborations that are designing and will build the huge detectors that will analyze the results of proton collisions at the SSC. The collaborations already involve more than half of the high energy physicists in U.S. universities and our other national laboratories. A comparable number of foreign scientists and their governments are investing significant amounts of time, effort, and money in planning these colossal experiments with us.

Careful review of the design and cost of these detectors is underway at the Laboratory right now. I want to emphasize that the experimental program at the SSC, as at other high energy physics laboratories throughout the world, is driven by the interest and involvement of an international scientific community. And that community is already turning to the SSC because of its promise of enabling the next major step in our understanding of the basic constituents of matter and the forces the govern them.

As a measure of its importance to the future of high energy physics, the Super Collider Laboratory was invited to host the International Conference on High-Energy Physics this summer in Dallas. The most important conference in modern high-energy physics, it is held every other year at different locations throughout the world.

A unique strength of the SSC is the partnership between the State of Texas and the federal government. Texas has issued $500 million in bonds of the $1 billion committed to the SSC. The state has committed $227 million toward the development and construction of the SSC through fiscal year 1992. This includes a one-time supplemental contribution of $60 million in 1991 when Congress did not appropriate the funds necessary to keep the Super Collider on schedule. Of the Texas contribution, $28 million has been used to support research at colleges and universities across the United States.

In addition to its $1 billion commitment, Texas has acquired nearly 10,000 of the 16,722 acres that will be needed for the Super Collider site. Land acquisition, which has been keeping pace with the project schedule, is expected to be completed in 1993.

As I have often stated, the SSC has two major goals: to create the world's premier high energy physics laboratory and to serve as a national educational resource. During 1992, more than 20,000 students, educators, and members of the general public will participate directly in the educational activities of the SSCL, including workshops, visits to the Laboratory, internships, teleconferences, and competitions. I would also like to point out that the Lubbock High School team representing the SSC Laboratory has won the National Science Bowl in the last two years.

Earlier this month, the University of Texas Southwestern Medical Center in Dallas, announced that they will build a cancer treatment facility adjacent to the SSC's linear accelerator.Doctors will use excess protons produced by the SSC's linear accelerator to destroy cancerous tumors. Medical Center officials say that the proton can kill certain tumors with fewer side effects than traditional radiation therapy, and they proclaim this to be a step forward in cancer treatment. This is an example of a benefit from the SSC that will be realized even before completion of the full project.

In the flurry of activity at the SSC, it is all too easy to overlook perhaps our most important accomplishment: the creation of a team of dedicated and talented individuals committed to exploring the unknown—to devoting a portion of their careers to creating, literally from "green fields," a great instrument and a great laboratory. In my view, this laboratory has brought together the finest group of academic scientists, industrial technologists, and laboratory researchers assembled since the Manhattan project and the development of radar during World War II. The United States has often been accused by other countries of being unable to carry long ad difficult projects to completion, of being an unreliable partner in international scientific and technical endeavors. Well, we are not unable to complete the SSC. The outstanding team of men and women from all walks of life who are gathered together at the SSC and in the industrial concerns that are participating with us in the

SSC are demonstrating on a daily basis that they can meet the challenges inherent in a project like this. If in fact we are prevented from completing the SSC, we will throw away not only the material and money already expended, but we will have wasted the physical, intellectual, and emotional investment of this exceptional team.

Over the past decade, the scientific community has recognized that the SSC is needed to advance high energy physics. Over the past five years, the U.S. Government has invested more than $1 billion in the Superconducting Super Collider. Over the past three years, the SSC Laboratory and DOE have been able, through strong management and clearly defined priorities, to keep the project within the baseline cost estimate. Underfunding the SSC each year clearly puts this remarkable track record, along with its estimated cost, in jeopardy. A shortfall in 1992 funding will have definite consequences for out ability to reach the 1999 completion date on schedule; it will also increase the final cost, hurt our attempts to secure additional foreign participation, and slow research being conducted by scientific teams in more than 100 universities across the country.

I believe strongly that a great nation, if it is to remain great, must undertake—and complete—projects like this. I hope the Senate will show the needed foresight to restore funding for the project at the level requested by the President. It would allow the SSC to continue on time and on budget and help to assure that this great scientific instrument makes its unique contribution to the search for answers to our most basic questions about the world we live in.

The CHAIRMAN. Thank you very much, Dr. Schwitters.

Next we will hear from Robert W. Galvin, who is the founder and chairman of the executive committee and former CEO of Motorola, Inc. He has served as chairman of the President's Advisory Committee on Private Sector Initiatives and is chairman of the Industrial Policy Advisory Committee to the U.S. Special Representative for Trade Negotiations to the multilateral trade negotiations under GATT. He is currently chairman of the board of trustees of Illinois Institute of Technology and is the recent winner of the National Medal of Technology.

Mr. Galvin.

STATEMENT OF ROBERT GALVIN, CHAIRMAN, EXECUTIVE COMMITTEE, MOTOROLA, INC., SCHAUMBURG, IL

Mr. GALVIN. Thank you, Bennett. I am going to direct, though in absentia, my comments primarily to Dale Bumpers and to his distinguished associates who are concerned, quite legitimately, with the issue of whether or not there are practical benefits in what we are doing here that are appraisable or estimateable, that are worthy therefore of the election of the outlay of funds at this time, in the best interest of our country.

I am not an engineer nor a scientist, though I did have the privilege of being awarded the National Technology Medal. I guess it is because it is the only compliment that I have ever received from my associates. I ran our company for over 40 years and they did not dare say anything nice about me, but finally as I reach the twilight of my career they said, Bob, we are lucky you were the head of our company and we think it is because you were not an engineer. You had more faith in what we could accomplish and you caused us to try harder, and as a consequence of that our company has grown.

My credentials are the credentials of time. I have witnessed the application of science for 50 years. When I started to work in the little company that my father founded back in 1940 as a high school kid, the total sales of the radio industry manufacturers in this country were $350 million. Our company was a teeny part of that $350 million.

What have I seen in 50 years? I can tell it to you in one sentence. I have seen 16 bits of surprises. They have accrued in the electronics business, which is the derivative of the radio business, circa 1990, was doing approaching $300 billion. That is, in very round decimal terms, almost 1,000 times growth. I am not trying to use statistics with precision.

Back in those early days all we knew was what kids knew in high school: electricity, magnetism. We saw something called the periodic table that had a few elements on it, and along came x rays and electrons and somebody said there was a thing called quantum mechanics and finally a transistor was invented.

As a consequence of those things, which I devote no time to technology explanations about, people were able to take the very simple things that the Marconis developed back around 1900 and convert that into, not a radio business, but into something called high technology and into electronics. I am just a surrogate for all the other sciences that might be represented by a businessman.

In anticipation of this privilege of speaking to all of you, I talked to a bunch of my engineer friends in our company. I have acquired five very short quotes from them that describe the direct relevance to this science to the development of the high technology industries.

The first is general. One of them said: "Atoms are the building blocks of all high technology industries and subatomic particles are becoming the building blocks." We actually build the platforms and/or the base structures of many of our integrated circuits one atomic layer at a time, and this is all accomplishable because of the brilliant seeds of knowledge that have been combed from the maze of scientific discoveries of gentlemen such as these that are sitting behind me.

Another of my engineers said: "Tell them about ions, Bob." What are ions? Well ions are atoms which have been partially stripped of electrons. Heavy ions, heavy atoms, can be focused in beams and perform a highly sophisticated milling or etching function in producing the most microscopic dimensioned integrated circuits which are essential for extremely high speed, high performance, defect-free, low energy consuming circuits.

An ion implantation is an outgrowth of accelerator research, direct relevance. Plasmas: Plasmas are gasses that are charged with Ions. The gasses act as carries of special atomic subparts and these atomic subparts are deposited on integrated circuit surfaces where they interact or they cause new actions or they cause the subtracting of unwanted materials.

Here is a direct relevance. Plasma was motivated and driven by nuclear fusion research. And Plasma etching, which I just described, is essential to accomplish the high technology purposes that you want accomplished in the development of our economy..

Another of the engineers said: "The presence or the absence of an atom or a subatomic particle and its interaction with other is determinative of the functional or the dysfunctional event that takes place in high technology." For example, they said, alpha particles. And I said what are alpha particles? And they said well those are helium atoms that are stripped of electrons and/or muons; are subatomic particles which, if they mysteriously get into the circuit, can cause soft errors.

Incidentally a soft error is not something to overlook. They really cause mysterious actions in our circuits and you cannot use them in defense or commerce or what have you.

X ray lithography is a very important tool to processing things in high technology. X ray lithography is derived from experimentations with accelerations and the cinratron—direct relevance. And the essence of the heart of a laser, which is another very exciting surprise that occurred in my lifetime, is the combination of subatomic materials that give off photons.

Well I could go on with nonengineering class of statements but which derive from my engineer's comments. My point is very simply this; there is absolute relevance between what has taken place up to this point in time, of all the steps that the scientists have given, have performed for us. They are merely in the process of taking the next, though very giant, step, they are, among other things, also developing great people to serve our needs.

Let me give you just one illustration of how significant this translates into application. I have here, to illustrate to you, a portable radio telephone which will be used in the iridium low earth orbit satellite communications system that will be flying in the skies and serving the earth this decade, if Motorola happens to be successful with its promulgation. We have four other American competitors who have something similar to this.

This portable radio can talk from any place on the earth to any other place on the earth: high mountain, low valley, remote village, downtown. Can you imagine what this will do to bring communication all over the world in the developing of a new communication system for the world, disaster relief, et cetera.

Now this will be a $4 billion investment when we put this up and around the earth. It could not have been done, could not be expected, if these men and their predecessors and all their great allies had not rearranged the atoms and the subatoms. Because inside here are very, very exotic, high technology items that are built on subatomic designs.

Four billion dollar investment: that will represent billions of dollars of business every year. I take you back to my numbers again. Remember I said that we are doing now, approaching—in American manufacturing business annually we are approaching $300 billion a year. That means in the last decade we have done a trillion or more dollars. There will be decades in the early part of this century where we will be doing tens and tens of trillions of dollars of high technology business in electronics only doable because of the practical relevance of what this science has translated into usable products.

I conclude with one extension of one of the great intentions of the founding of our country. I think, incidentally, it is far more significant than anybody has given it credit for in the history of our country, but I refer you to that opening phrase in Article 1, Section 8 of the Constitution that addresses most particularly the inventors clause or the progress clause. I remind you that it says "Congress shall have the power to promote progress in science and the useful arts. . . ."

I have read a lot about the founding process of our country; I think Madison had a heck of a lot more in mind than just getting the patent system started. I respectfully suggest that just as we have had, in business, the confidence and the courage, even when things were tough to budget, to spend for research and development, that Congress shall have the power to promote progress in science and the useful arts will be its greatest legacy in terms of converting to benefits, wealth creation for our society.

[The prepared statement of Mr. Galvin follows:]

PREPARED STATEMENT OF ROBERT GALVIN, CHAIRMAN, EXECUTIVE COMMITTEE, MOTOROLA, INC., SCHAUMBERG, IL

THE IMPORTANCE OF THE SSC TO SCIENCE, ENGINEERING, AND ECONOMIC DEVELOPMENT

Human progress depends on high technology industry. During our lifetimes, we have watched as our productivity has been increased 100 fold by the techniques now available to us to automate machinery, to transform materials, and to transmit information. The U.S.A. can hope to remain economically competitive and to preserve its high standard of living only if our industry remains at the forefront of technology.

Engineering for industrial improvement is based on science. Occasionally, basic discoveries have almost immediate application to the marketplace: a good example was the discovery of the transistor in the basic research of Bardeen and Brattain. Usually, many discoveries fit together to give an increasingly profound understanding of phenomena and then the engineers use this understanding to develop practical devices. The engineers, as the problem solvers of our society, must have close connection with the scientists in order to apply scientific understanding to give useful and marketable products. Thus engineering is continuingly transformed by the science on which it rests.

There is indeed a two way transfer between the scientists and engineers, as the engineers provide tools for research. The laboratory of today is filled with automation and fast electronics that make possible, experiments unthinkable during my youth.

Medicine and high energy physics may seem to be remote from each other, but they indicate how research in different areas may combine to give useful applications. High energy physics always presses the capability of computers to analyze automated data on collisions. The techniques required in high energy physics have then been applied in other areas. For example, the diagnostic techniques used in medicine have been greatly improved through computerized axial tomography (CAT) and magnetic resonance imaging (MRI). A high energy physicist, Alan Cormack, shared the 1979 Nobel Prize in medicine for his contributions to the reconstruction of images from detector data, leading to the techniques used in CAT scanning today. MRI technology has been greatly advanced by the improvements of superconducting cable that resulted from the building of the Tevatron at Fermilab, the first major high energy accelerator utilizing superconducting magnets.

Proton accelerator technology developed for high energy physics is now being utilized in medicine. For example, protons can be focused to give a more localized destruction of cancer cells than other methods of cancer therapy; this approach has been pioneered by Fermilab, and a proton accelerator is now used for cancer treatments at the Loma Linda Medical Center in California. Last week the SSC Laboratory and a nearby medical center announced plans for similar future use of an SSC Laboratory proton beam for cancer therapy.

Using accelerators, scientists continually examine nature in increasing detail. They have shown how ordinary matter is composed of molecules which in turn are broken up into atoms formed of electrons around nuclei. Nuclei have been shown on further magnification to be made of neutrons and protons, which in turn are described as composed of quarks held together by gluons. Scientists are increasing understanding of how to transform matter from one state to another, even to release nuclear energy. Already fission energy has been tamed, and fusion energy is likely to provide the future energy source needed by mankind, after fossil fuels have been mostly exhausted.

Understanding of the quantum theory and statistics of radiation led to modern communications and lasers. These devices developed only a generation ago in the laboratory now are operating in many households and offices in video cassette recorders and printers. As science goes to smaller dimensions, engineering follows. Computers process data billions of times faster yet take less space than a generation ago.

Life scientists now work at the atomic level; having unravelled the genetic code, they have learned how to alter genes and thus to design new life forms, with many practical applications to medicine, agriculture, and chemical industry.

As science advances in many directions, the most fundamental research examines the basic interactions of nature. Quantum theory provides that at high energy the wave length that is associated with a particle varies inversely as its energy. The SSC, by providing energies 20 times greater than any previous accelerators, permits nuclear collisions that examine very small distances and thus magnifies twenty-fold our ability to look at the most basic interactions of matter. There is no other way to reach such small dimensions with adequate intensity in the Laboratory than by building the SSC. It will provide a tremendous advance in scientific understanding of natural laws.

The SSC will produce over one hundred million collisions per second, each involving creation of about one hundred massive particles. In effect, this means a hundred trillion bits of data available per second. No modern computer can handle such amounts, so extremely fast and clever electronics are necessary to analyze the data and to decide which information might be needed for important discoveries. SSC experiments will stimulate advances of computers that will have broad application throughout society.

Combined with information from many other sources, the SSC will give discoveries that will set the tone for the science of the next century. The engineering of the next century will then be transformed by science just as our engineering has been.

The SSC will have many important benefits in addition to its research discoveries. As the world's most fundamental scientific instrument, the SSC will attract many of the best scientists and engineers from overseas; they in turn will make their talents available to other needs in our society. The SSC will also serve as a powerful stimulus for improvements in mathematics, science and engineering education.

The CHAIRMAN. Thank you very much, Mr. Galvin.

Finally, I would like Assistant Secretary Joe Cipriano to come to the table to be available for questioning. Secretary Cipriano is the SSC project manager for the Department of Energy.

Mr. Cipriano I would like to ask, very briefly, do you concur with Dr. Schwitters in saying that this project is on time and on budget?

Mr. CIPRIANO. Yes, sir, I do.

The CHAIRMAN. There is about a billion dollars invested. I understand there is about a billion dollars in inflation built into this between now—in other words these are not real dollars, these are as spent dollars.

Mr. CIPRIANO. That is correct. The $8 billion number includes over a billion dollars in escalation.

The CHAIRMAN. That would be a termination cost. So if you took off the inflation, the termination cost, and the invested dollars, what would be the net savings if we terminated this project today?

Mr. CIPRIANO. The net savings to the Federal Government would be $4.3 billion.

The CHAIRMAN. $4.3 billion.

Mr. CIPRIANO. Yes, sir.

Senator WALLOP. Mr. Cipriano, did you say over what period? Between now and 1999?

Mr. CIPRIANO. Between now and 1999, yes, sir.

Senator WALLOP. So that in essence you are talking a savings of, what, about $400 million a year.

Mr. CIPRIANO. Yes, sir.

Senator **Bumpers**. Mr. Chairman, may I just—for Mr. Cipriano, based on the question you just asked him, can I ask one question at this point?

The **Chairman**. Yes.

Senator **Bumpers**. I do not want to tear up the procedure of the committee here, but I do think this is an appropriate time to ask this question.

The **Chairman**. Yes, go ahead.

Senator **Bumpers**. Mr. Cipriano, have you read the GAO report on this report?

Mr. **Cipriano**. The——

Senator **Bumpers**. The GAO report.

Mr. **Cipriano**. Yes, sir.

Senator **Bumpers**. Are you familiar with the point where they state: Although DOE maintains that the SSC project is on schedule and within budget, it does not have in place an integrated system for monitoring cost and schedule performance that would allow it to objectively determine its progress.

What is your comment on that?

Mr. **Cipriano**. That report was written based on assessments that were made very early in the program in 1990, in early 1990.

Senator **Bumpers**. Well this is a 1992 GAO report.

Mr. **Cipriano**. That is when the report was issued, but it was reporting on data that was gathered much earlier than that.

Senator **Bumpers**. So what is your response?

Mr. **Cipriano**. Those systems are now in place and have been.

Senator **Bumpers**. Thank you, Mr. Chairman.

The **Chairman**. Thank you.

Dr. Lederman, you are the current president of the American Association for the Advancement of Science.

Dr. **Lederman**. Chairman of the board, Mr. Chairman.

The **Chairman**. Chairman of the board. Now that includes more than just particle physicists.

Dr. **Lederman**. Yes, they are a very small component. It is an umbrella science organization which has about 230 member societies in science across the board and engineering.

The **Chairman**. Can you say whether the American science community supports this project?

Dr. **Lederman**. Well, sir, it is not an easy statement. I am well aware, as all of us in universities are, that there are colleagues who are worried about the issue of the SSC; we have to face that. We debate with them and argue with them, and fundamentally, the problem comes down to the fact that all science in this country is under stress. There is a general feeling of loss of morale in the science community because of the budgets have just not kept up with inflation and with the increasing costs of doing research.

Whenever you have that, let me say that whereas the science is magnificent, scientists are people, in case you have not noticed. They are very worried about their own budgets and they are worried about the impact of the SSC on their own budget. In all fairness, there is no way you can say that the SSC has, up to now, impacted on other budgets, and I did make a study of previous projects.

After all, the Fermilab, in 1990 dollars, was a $2 billion project, not very small, and built from 1967 to 1972. In a very careful study of all the other sciences at that time, it failed to show any negative impact of the construction of the Fermilab on other sciences. On the contrary, in those days high energy physics was about 12 percent of the basic research budget and today it is about 7 or 8 percent, which means that other sciences have come to the fore and taken a bigger share of the budget and that is all to the good.

So let me sort of comment. We have a lot of support across the board among all sciences, but there is a lot of opposition, just as was mentioned, there is a lot of concern. I do not think of anybody—I know of no scientist who has criticized the scope, the grandeur, the ambitions scientifically of the project. There may be skepticisms about the pace, there might be skepticisms about the cost estimate, but the science is always granted as being first rate and magnificent.

As I said, the primary concern out in the scientific community has always been: Is this going to impact negatively on my budget. That is human.

The CHAIRMAN. Dr. Lederman and Dr. Smoot, I have heard you describe this project as being at the intersection of more than one branch of science. In other words, you must get the information from this project in order to do proper investigation and prove up theories of cosmology, as well as the innerspace of the atoms, as well as the unification of the forces.

This, I take it then, is just not another one of those machines, but this machine is unique and vital and essential in those investigations. Have I put that reasonably correctly?

Dr. SMOOT. Yes, Mr. Chairman, you have. I think it is very critical. If there was not a link to cosmology, the high energy physics science would be very compelling. The fact that it ties to our understanding of the early universe makes it absolutely essential, and there is no other way for us to get this data.

The CHAIRMAN. Now this machine is very much different in scale from CERN, for example. What is the electron volts at CERN?

Dr. LEDERMAN. The CERN machine, it is uncertain how much energy it will reach. It is constrained to a preexisting tunnel and the energy of the machine depends on the size of the tunnel and on the technology of magnets. So what their energy will be at most—at most it will achieve an energy of something like 15 TEV, as contrasted with the SSC's 40 TEV. Roy, do you want to?

Dr. SCHWITTERS. Yes, let me—what Leon described is a proposed extension of the CERN machine. The one operating now in the tunnel is a very fine device that operates at .1 TEV, whereas we will be at 40 TEV.

The CHAIRMAN. A trillion electron volts.

Dr. SCHWITTERS. A trillion electron volts. So the factor today is 1/400th. What is being discussed in Europe is a proposed extension of the supermagnet technology in the same tunnel. As Leon Lederman indicated, the maximum energy that could be achieved, because of the much smaller tunnel, would be roughly one-third of what is possible.

The CHAIRMAN. Well now, Dr. Lederman, why is the amount of energy so vital in this endeavor?

Dr. **Lederman**. As I tried to say, the parameters of the SSC were driven, more than any other machine I can remember, by the science that we had to investigate. In the jargon of the physicists it is called the 1 TEV in the center of mass scale. It is at that scale that we can confront the Higgs. Or if Higgs is not the ultimate answer, it will be something else.

It has been contrasted to the voyage of Columbus who said either I will find the West Indies or I will find something more interesting. Something has to happen there, we know, which will be new physics. Whether it is Higgs, which is a likely thing, or some other new discovery, it has to be made.

Our problem with our European colleagues is that with all the blood, sweat, and tears and the efforts of so many scientists and engineers to build a machine even at a third of the energy of the SSC, the fact that they have compromised the energy puts in that much more uncertainty that they will be able to address the basic issues for which we have decided to build the SSC.

So we calculated the energy we need based on all the things we know. We arrived at an energy, with a certain small amount of safety factor, of 40 TEV. And we have looked very carefully at trying to descope the machine, and we found that any descoping would compromise our objectives.

The **Chairman**. Mr. Cipriano, you mentioned that if we terminated the project today we would save $4.3 billion over a period of years. Now you also have built into this about $800 million, am I correct, in contingency fees?

Mr. **Cipriano**. Yes, sir, that is correct.

The **Chairman**. What are your chances of being able to save some of that $800 million in contingency fees?

Mr. **Cipriano**. From what we know right now, I think quite good. If you will look at how you can spend money: you can spend money on labor, you can spend money under contracts. And we look at our labor costs versus how much work we are getting done; we look at our contracts costs versus our baseline cost estimates for those contracts, which do not include contingency. From what it looks like today, it looks like we have a good chance of being able to complete the project without spending all the contingency, assuming that the Congress is able to provide us the funding on the profile that we requested.

The **Chairman**. So that would reduce the savings below $4.3 billion, if you can save some of that contingency fee.

Mr. **Cipriano**. Yes, sir.

The **Chairman**. Now one construction contract has come in a little above its estimate and others are coming in below. The tunneling, I think, is 15 to 20 percent below the baseline. Is that correct?

Mr. **Cipriano**. That is correct.

The **Chairman**. So the chances of being able to save even more out of the $800 million are quite good.

Mr. **Cipriano**. Yes, sir.

The **Chairman**. One final question, what is your degree of confidence in these estimates of cost? I mean assuming it is funded as we project, what is your degree of confidence in those cost estimates?

Mr. CIPRIANO. As you have heard Dr. Schwitters give his estimate, my staff's job is to independently estimate. We do this on a daily basis, as well as having monthly reviews where we monitor the progress, technical progress as well as financial process, in each area of the program.

We have one of these every month and based on those reviews and the independent assessments of my staff, as well as the inputs I have received from Dr. Schwitters and his staff, I am very confident that we can complete this project for the amount of money that has been estimated.

The CHAIRMAN. Thank you.

Senator Domenici.

Senator DOMENICI. I would yield to Senator Bumpers if he wants.

The CHAIRMAN. Senator Bumpers.

Senator BUMPERS. Secretary Cipriano, are you aware of any briefing by the GAO to the House Science, Space, and Technology Committee staff in the last 2 weeks?

Mr. CIPRIANO. No, sir, I am not.

Senator BUMPERS. Regarding whether this thing is on time and under budget.

Mr. CIPRIANO. No, I am not.

The CHAIRMAN. Excuse me, are you referring to the Inspector General's report or the GAO?

Senator BUMPERS. Is it the Inspector General. I thought it was the GAO staff briefed the House staff.

Mr. CIPRIANO. I am not aware of such a briefing.

Senator BUMPERS. Mr. Chairman, I want to insert in the record* a letter dated June 24, 1992—just a few days ago—by the chairman and ranking member of the Committee on Science, Space, and Technology. The letter is to Secretary Watkins. And they say—I will just read two paragraphs of it; it is a very lengthy letter. I assume you have seen this, Mr. Cipriano. Have you?

Mr. CIPRIANO. I have not seen the letter. I have seen some letters, I do not know if I have——

Senator BUMPERS. Well have you seen this specific letter dated June 24 from the chairman and the ranking member to Secretary Watkins?

Mr. CIPRIANO. Yes, I believe I have.

Senator BUMPERS. It starts out:

> On June 15 we had a Dear Colleague letter delivered to the 435 elected officials of the House. Our letter pointed out that while the Department has consistently professed to Congress that the SSC is on time and under budget, internal DOE communications indicated otherwise. We specifically pointed to language in a January 24, 1992 letter signed by Deputy Secretary Henson Moore which stated that crossgrowth problems in conventional construction were continuing and maybe even getting worse.

And then the last paragraph that I want to cite is:

> We could discuss the claims of being on time and on budget, though for quite some time the slogan was on time and under budget; the efforts to sole source contracts aboard; the problems of the geology that have forced the SSC lab to move the huge detector halls; or the dozens of configuration control board requests. We could remind you of your claims contained in a letter delivered to us on May 8, 1991—that is roughly a year ago—that DOE had no chance to see or comment on GAO's

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* See p. 5.

work when, in fact, DOE had made such comments and some of them were incorporated in the GAO's report on the SSC. We knew this because the Department's written comments were in the possession of our subcommittee.

We could remind you that last July you sent us a letter stating that all relevant materials in response to our document request had been delivered, and within a month we had discovered that secret back-channel reports from Mr. Cipriano to you had been withheld from the subcommittee.

Is that an accurate statement, Mr. Cipriano, or not?

Mr. CIPRIANO. It is not. There are several inaccuracies, and let me try to address them as I can. The first issue—what was the first issue they brought up?

The first issue brought up was relative to Henson Moore's letter to the laboratory. That was one of a series of events that took place. Both the laboratory and my office were aware of the fact that we were having some problems in conventional construction and we had underway some—in fact had asked the Inspector General's Office to look at this area and help us refine corrective actions for the problems that were being seen so that we could get them fixed before they became big problems.

Again, this is very very early in the program. We are talking about 1990; we had only built one building and only spent a couple of million dollars in actual construction. And we wanted to get our work processes fixed as early as we could, to avoid cost overrun problems. So we had investigations going underway.

We had briefed the deputy secretary on the progress of that in August. He was frustrated. I had—I was briefed in December by the IG on the progress of their investigation and had written a letter to the laboratory asking them to address how they intended to correct the problems that were being identified. In January the Deputy Secretary added his reinforcing statement that he wanted these problems corrected as soon as possible. We have, since that time, instituted corrective actions for the problems and the IG auditors have concurred that our corrective actions are responsive to their concerns.

Relative to some of the other points that were raised, the issue of secret memorandums: The Secretary had asked me to report to him directly, biweekly, my personal assessment of how things were going. This was in addition to all the formal reporting that went on. These reports contained comments about individual performance changes I thought the Department might need to make and how they were conducting business in different areas, as well as my very frank assessments of the program.

At the time that those assessments were made, they were in advance of the time when anything of certainty could be made. They were just my gut feeling. We had no data, and I was trying to give him a feel for how I thought things were going. I told him in one of those reports about the problem we were having in conventional construction, and so he was aware of it back during that time frame. This is the same problem that we keep discussing. And I told him that I thought that problem was on the order of a $50 million problem, it could be as great as that kind of a problem, a call on contingency for that amount if we did not get it corrected, and I advised him of our actions.

Now the reason those reports were not presented to the committee when they were first asked for was because I was not aware they existed. Our habit was to send one copy to the Secretary for his eyes only, because they were very personal and dealt with personalities. And I had no copies in my office. I was not aware that there were any copies in existence, and I think neither was the Secretary.

What was later found was that somebody in the process of getting that to the Secretary had kept copies of them, and so we did find we did have them and provided them to the committee.

Senator BUMPERS. Well Mr. Cipriano, my concern is that this committee, the Energy Committee on which I sit, as well as the Appropriations Committee, that we not be getting two reports: one is that everything is just hunky dory, and other internal memo which says we have big problems and they are getting worse. Now we cannot act responsibly on this one way or another with conflicting testimony.

I will not pursue that any further at this point, Mr. Chairman. Just a couple of other insertions in the record.* One is from Dr. Bloebergen, who is president, or was president last year of the American Physical Society, a letter addressed to Dr. Richard Carrigan, head, I guess, of a division of Fermilab. Secretary Moore had stated in a letter that magnetic resonance imaging is a spinoff from the activities of accelerator research done at Fermilab and SSC.

And Dr. Bloebergen goes on to say: "When I testified subsequently at the same hearing, I inserted in my oral presentation the following, 'As an expert in magnetic resonance, I wish to correct a statement in the testimony by the Honorable Mr. Moore. I can state categorically that MRI is not a spinoff from SSC-related activities.' " He goes on to say "MRI would be alive and well today if Fermilab had never existed."

Senator BUMPERS. Another letter——

The CHAIRMAN. Why do you not let him answer that.

Dr. LEDERMAN. Yes, I think so. I was there and listened to that statement. I think the facts are the following: Before Fermilab came on the scene, the total production of superconducting materials—and John Peeples back there can correct my number—was a few hundred pounds nationally. Fermilab invested what was then a huge sum of money in the R&D on materials for superconductors.

In the early seventies through 1980 the amount of superconducting material zoomed up to thousands of pounds. We had a lot to do with industry in the technology of these exotic alloys, and I think that it is clear that the MRI is one example of a medical instrument which depends on superconducting materials. Those materials were developed on behalf of Fermilab by the industries, and I think there was a substantial advance, not in the concept of MRI, which is a nuclear physics concept, but in the technical ability of what is now a $500 million industry in medical instruments.

That came, I think—I mean it was largely influenced by this pioneering evolution of technology which Fermilab needed to build magnets to study the properties of quarks. It is a beautiful, positive example of interface of many sciences.

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* See p. 12.

The key idea for MRI was discovered by my mentor, I.I. Rabbi at Columbia University. Why? Because he was interested in the properties of nuclei and whether they had magnetism. That evolved. They developed an instrument—they discovered magnetic resonance. The chemists used it to advance chemistry and eventually it became a very powerful medical diagnostic. So it is an accumulation of the contributions of many sciences, including the work at Fermilab.

Senator BUMPERS. Well do you disagree with the statement that MRI would be alive and well if Fermilab had never existed?

Dr. LEDERMAN. The question is what he means by MRI. If you are talking about the medical diagnostic industry, I would disagree with it. If you talking about MRI as a scientific tool, you could do it with a few hundred pounds of superconductors; you can even use magnets which are not superconductors. But the medical application is the thing which is—something like 25 companies are now involved in the building of these instruments, very much depended on a spinoff of the technology of superconducting materials.

Senator BUMPERS. Dr. Lederman, let me say that I am opposed to this primarily on budgetary grounds. But the reason I pursue that is I do not want it to pass on false claims of the spinoffs. This committee has a right—and I know you share that—for us to know precisely what benefits, if any, there are going to be to the public in whole: scientific, medical or whatever. And that is the only reason I raise that point.

Dr. LEDERMAN. I think it is a good point.

Senator BUMPERS. I just do not want us voting on a project that is probably going to be between $8 and $12 billion, based on something that is inaccurate.

The CHAIRMAN. Senator Bumpers, where is the basis for that $12 billion? I mean it just does not exist, I do not believe. I mean we have got the people here to tell us the cost.

Senator BUMPERS. Well, the lifetime cost, Mr. Chairman, is $20 billion. Everybody admits that the lifetime 25 year cost of this project is now $20 billion. And I remember when Admiral Watkins came before this committee in 1987 and told us about this magnificent new super collider, it was going to cost $4.4 billion. Everything here starts at $4 billion. And then 2 years later he came back and said the cost is up to $5.9 billion and if it goes a penny above that, I will not support it. Now we are up to $8.3 billion and the greatest champion, of course, is Secretary Watkins.

Now to suggest that this project, for which ground has hardly been broken, is going to remain at the present projected cost of $8.3 billion just conflicts with everything I have ever seen in the 17 years I have been in the Senate.

Dr. LEDERMAN. May I make one comment, maybe Roy will also. Our track record is pretty good. The Fermilab—again, let me go back to the thing I know best—was authorized and appropriated $250 million in 1967. It was designed for a 200 billion volt machine with 7 beam lines. In 1973 the machine went to 300 billion volts and then eventually, a year later, to 400 billion volts—twice the specified energy with 14 beam lines, twice the facilities for doing research—and there was $10 million left over, as an example of the fact that we have a good track record.

Our machines generally come in, if not on schedule, on budget, reasonably within the budget; we are talking about 10, 20 percent, perhaps. I think that track record is a very good one. I hope Roy will address the issue of the $4.4 billion.

Dr. **Schwitters**. Yes, let me just add to that. This has been looked at in great detail with our other great laboratories. The SLAC machine had a similar track record to making these projects come in on time and budget. And the reason is actually rather straightforward. There is no incentive not to. The incentive is to do science with these machines and get on with it, and that is what drives the entire staff.

Now with respect to the figures, sir, that you quoted, it is true that in the first year of this project Admiral Watkins presented a budget to the Congress, the President did, of a total project cost of $5.9 billion. That had within it the $4.4 billion figure that was mentioned. It included some pre-operations figures and detectors. So the $4.4 billion and the $5.9 billion are the same thing, they are not different.

The figure that was presented to the Congress when the laboratory was formed was $5.9 billion. We then, as I said in my testimony, began to gather the team of builders around us. We took a hard look at the real site. We had people who had to really commit to building this thing. We had some new information on the behavior of the stored beams in the critical superconducting magnets.

We made a judgment. The judgment was that we had to make this machine robust and absolutely reliable and stable, to be worthy, if you will, of the huge investment of money and time and effort that would be going into it. That was a critical time. In early 1990 we presented those figures, after 1 year, to the Department of Energy. We had soul searching. Should we reduce the scientific scope or should we ask the Government for some more money?

It was a very trying time because we were aware of our responsibilities to hold the budgets. We made the determination that the science was so important that we could not afford to miss the window of the physics that was presented here. The laboratory and various esteemed advisory committees all recommended that we go back to the Government and ask for more. That was the one time that the budget went from the $5.9 billion level to the $8.249.

Senator **Bumpers**. Dr. Schwitters, let me interrupt you just a moment. Were you a part of DOE's independent cost estimate on this project? Did you participate in that?

Dr. **Schwitters**. We presented materials to the Department of Energy during that period. They had several—in May and June of 1990 we presented a lot of detailed information. I will never forget it. We had 919,000 pieces of paper xeroxed for these presentations, a great deal of detail.

Senator **Bumpers**. That is not much for around here.

[Laughter.]

Dr. **Schwitters**. It shook me up, I will tell you. Anyway, at that time there was a formal review by the program offices in DOE. Then operating at the same time, raising other questions of our staff, was the independent group. No, I did not assemble those numbers; that was an independent group.

Senator BUMPERS. Well do you know what their conclusion was?

Dr. SCHWITTERS. The conclusion that I am aware of was published in the Department's so-called green book, which was the transmission to Congress in 1991 of what we all agree is the baseline budget. We have looked at those budgets.

Senator BUMPERS. Just give me the figure, Dr. Schwitters. I do not want to say it; I want you to say it. What was the figure?

Dr. SCHWITTERS. The budget, on the same basis, was $8.3 billion.

Senator BUMPERS. You have not seen the congressional research report that shows that DOE's independent cost estimate group said that the project would cost $11.8 billion?

Dr. SCHWITTERS. I have seen the figure in there, but it does not refer to the same sets of items. It is apples and oranges.

Senator BUMPERS. What is the difference in the two?

Dr. SCHWITTERS. It has to do with financing for the experiments. We were willing to take a reduced amount there in order to get on with the physics, and other items in there.

Senator BUMPERS. Let me ask you another question, Dr. Schwitters. On the magnets and the $8.3 billion estimate, can you tell me what the project costs of the 8,600 dipole magnets and the 1,600 quadrapole magnets is?

Dr. SCHWITTERS. About $2 billion.

Senator BUMPERS. And that is based on how much per magnet? Do you know what the present projected cost of the dipole magnets are?

Dr. SCHWITTERS. Roughly $150,000.

Senator BUMPERS. Do you know what the Japanese say about that?

Dr. SCHWITTERS. The Japanese have been working with our people to understand those figures. And, in fact, the latest we know is that they have described—in fact, Joe Cipriano can report to you, he was there—they have described our cost estimates as being reasonable.

Senator BUMPERS. Well here is a—just a moment, Mr. Chairman. According to Dr. William Happer, the Director of DOE's Office of Energy Research, the Japanese are reported to think the cost of building superconducting magnets will be two to four times higher than DOE has estimated.

Dr. SCHWITTERS. Yes, Will Happer——

Senator BUMPERS. As a matter of fact, they say $500,000, could go to $640,000. The $500,000 figure would increase the cost of the project by $3 billion.

Dr. SCHWITTERS. Those initial estimates were based on planning assumptions that did not take into account what we are actually doing in our laboratories. So we presented them with details of cost records, budgets, actual procurements of materials. They were simply not aware, at the time those were made, of our design techniques, of our tooling techniques, and manufacturing techniques.

Since that time, there have been extensive discussions with their engineers. And as I said, the final result of that has been a description to us that they think they are reasonable. So this was an early projection, sir, that was made before they had the opportunity to talk these over with the experts who are now building magnets.

Senator BUMPERS. So you are telling this committee that you think it highly likely that the magnets will come in within the $150,00 figure.

Dr. SCHWITTERS. Yes, sir.

The CHAIRMAN. Dr. Happer, by the way, is in the audience, whom you were quoting a moment ago.

Senator BUMPERS. Well why do we not just let him stand and verify what I just said: either to verify it or deny it.

Dr. HAPPER. Well, I was reporting what was in the Japanese newspaper. Of course, it was a very early cost estimate. I would agree entirely with what Dr. Schwitters says. I have worked with the Japanese, and they are sharpening up those estimates quite a bit and they are much closer to ours now.

Senator BUMPERS. Dr. Happer, is it your job in the Department to—are you sort of a liaison with the Japanese on this?

Dr. HAPPER. Well, I am one of the U.S. co-chairman of the joint working group with the Japanese.

Senator BUMPERS. Are you familiar with the letter that was sent over to the House Space and Technology Committee in 1989 saying that—I think the secretary said that it was a crucial time in the negotiations with the Japanese, and therefore the House ought to continue this project because of the very critical nature and time of the negotiations with the Japanese. Are you familiar with that?

Dr. HAPPER. Well that was before my time in this job, but I am sure that is true.

Senator BUMPERS. Thank you. Now, Mr. Galvin, let me ask you, do you know George Fisher?

Mr. GALVIN. Yes, sir.

Senator BUMPERS. Who is he?

Mr. GALVIN. He is the chief executive officer of Motorola today.

Senator BUMPERS. And he is also a member of the Council on Competitiveness headed up by Vice President Quayle.

Mr. GALVIN. He is.

Senator BUMPERS. Are you familiar with a statement that they made about science and technology and the limited resources we have in this country?

Mr. GALVIN. I am.

Senator BUMPERS. Do you agree with it?

Mr. GALVIN. No.

Senator BUMPERS. So and your—I do not know, I would not call him your superior, Mr. Galvin. But you and Mr. Fisher are at odds on this; is that correct?

Mr. GALVIN. Based on that public statement we are. I do not think we are that far apart. If you caused us to discuss the issue together with you, you would find that his is particularly noted because of a selection criteria that is slightly different than mine. But when we finally talk about what is essential to our science and our engineering in the future, I think you would find us rather close together.

Senator BUMPERS. Are you familiar with the statement last year by Dr. Eric Bloch, director of the National Science Foundation from 1984 to 1991, in which he said: "I would emphasize competitive-based technologies, big programs such as the SSC and the space station, come last." You disagree with that too, I take it?

Mr. **Galvin**. I disagree with that.

Senator **Bumpers**. Do you have a position on the space station, Mr. Galvin?

Mr. **Galvin**. Yes, sir.

Senator **Bumpers**. Do you favor it?

Mr. **Galvin**. Yes.

Senator **Bumpers**. Do you realize that the American Physical Society, almost to a person, opposes it?

Mr. **Galvin**. No, I did not know that one way or another.

Senator **Bumpers**. Well that is a fact.

Mr. **Galvin**. Thank you.

Senator **Bumpers**. You know, Mr. Chairman, I have several more questions. I am taking up too much time of the committee.

The **Chairman**. Senator Bumpers, go ahead, take the time you need.

Senator **Bumpers**. I have several questions that I want to submit in writing, but I will just make a comment here.

First of all, Mr. Chairman, I never did get a letter in a moment ago that I wanted to put in the record also, from James—I guess it is Krumhansl, who was also President of the American Physical Society,* and his letter is to the *New York Times*. And he says that he would like to make this point, and I will just read this and then insert it in the record.

And this is absolutely not intended as any reflection on the most prestigious audience and panel, I guess, that has ever appeared before this committee. We value your expertise; we value your contributions. That is not precisely the issue here.

But he says:

> I would like to add some brief points for your consideration, both as past president of the American Physical Society and as a physicist. The super collider is a heroic but very specialized experiment in science. In physics today there are at least 18 identifiable subfields in the American Physical Society, and there are 40,000 members.
>
> Particle physics represents about 8 percent of the field, and in spite of its proponent's suggestions is surely not the only important area, nor most fundamental. Particle physics is also specialized to the extent that it has not made, and cannot by its nature make an impact on most other areas of physics, on chemistry, on biology, and on electronics or any other science, except perhaps astrophysics and cosmology.
>
> As to funding in a climate of limited resources, perhaps 1,000 particle physicists might be served by the SSC at a construction cost of over $8 billion. This amounts to a 10 year grant of $5 million to each individual particle physicist involved. The average grantee from NSF is struggling for a 1 year grant of $40,000.

There is much more and I will just insert that in the record.

The **Chairman**. If you would yield at that point, I have a letter from Ernest M. Henley who is president of the American Physical Society. The letter is dated June 29 of this year. He sends to me a statement of the executive board of the American Physical Society on the superconducting super collider, which was adopted on Friday, June 26, 1992 which says as follows:

> The executive board of the American Physical Society is dismayed at the recent vote of the U.S. House of Representatives to terminate funding for the superconducting super collider. While we strongly reaffirm the position of the APS council

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* See p. 13.

that funding for the SSC not come at the expense of the broad base of American science, termination of the SSC would seriously disrupt progress in elementary particle physics.

Moreover taken at this late point, cancellation of such a highly visible project would send a message to the world that the United States is relinquishing its long-standing commitment to fundamental scientific research. Such a perception could not fail to have serious consequences for the long-term interests of the Nation.

I would like to put that in the record.

[The letter referred to follows:]

The American Physical Society
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June 29, 1992

Honorable J. Bennett Johnston
United States Senate
SH-136 Hart Senate Office Building
Washington, DC 20510-1802

Dear Senator Johnston:

The Executive Board of the American Physical Society issued the enclosed statement on the Superconducting Supercollider at its meeting on Friday, 26 June 1992. We hope this statement can be included in the record of the Energy and Water Development Committee hearing on the SSC scheduled for 30 June 1992.

Sincerely,

Ernest M Henley

Ernest M. Henley
President

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STATEMENT OF THE EXECUTIVE BOARD OF THE AMERICAN PHYSICAL SOCIETY ON THE SUPERCONDUCTING SUPERCOLLIDER

26 June 1992

The Executive Board of the American Physical Society is dismayed by the recent vote of the US House of Representatives to terminate funding for the Superconducting Supercollider. While we strongly reaffirm the position of the APS Council that funding for the SSC not come at the expense of the broad base of American science, termination of the SSC would seriously disrupt progress in elementary particle physics. Moreover, taken at this late point, cancellation of such a highly visible project would send a message to the world that the United States is relinquishing its long-standing commitment to fundamental scientific research. Such a perception could not fail to have serious consequences for the long-term interests of the Nation.

Senator **Bumpers**. Well, Mr. Chairman, I think we perhaps ought to get some kind of letter a little clearer than that. Because it is my understanding the American Physical Society has endorsed this only so long as it does not come at the expense of other science. Now that clearly is a choice for Congress to make. Is this going to jeopardize other science or is it not? And if it is, is it worth it?

Those are the fundamental questions we have to ask. Obviously particle physicists, for all the understandable reasons, very much want to this. Let me say to all of you, you know, I guess the best way to talk about why we have a $4 trillion debt, which a lot of people like to lament around here, is because of fragmented interest groups in this country. And we just simply cannot do it all.

I will tell you a story I have told the chairman before, a great story about when Huey Long, during the depths of the depression, was running for reelection as governor down in Louisiana, preaching the rich caused it all, that is the reason they were all hungry. The rich got it all; they got nothing. He was preaching let us share the wealth.

And he was talking to these farmers and he picked out a farmer that he recognized by name and he said Pete, let me ask you. If you had three Cadillacs, would you be willing to give one to the people of this State that ain't got a mule or a buggy to get to church on Sunday morning. Pete said I sure would, Governor. And he said Pete, if you had $3 million, would you be willing to share a million of it with the people of this State that ain't got grub on the table. He said you could count on it, Governor. And he said Pete, if you had three hogs—Pete said hold on a minute, Governor, I got three hogs.

[Laughter.]

Senator **Bumpers**. Now those are the kinds of things that we have to referee around here, because everybody can see their own interests in quite clear terms.

Mr. Chairman, just a moment.

The **Chairman**. I would just note while you are looking for something that the United States, at this time, has the scientific leadership of the world. And this has to do with giving that away, at least in major part.

Senator **Murkowski**. Mr. Chairman, while he is looking I have one question.

The **Chairman**. Yes, please.

Senator **Murkowski**. Thank you, Mr. Chairman. I think that we can observe the discussion here relative to almost a business proposition; what is the return on the investment to the economy of the United States. And it is a legitimate discussion and the difficulty sometimes we have on this side is finding accountability.

Because if this prospers and progresses at the expenditure you suggested, and indeed it provides the return on research plus all the other unknowns that have been commented on here, the contribution over an extended period of time will be substantial. On the other hand, as has already been mentioned, we walked away from Clinch River at a cost of about $2 billion or thereabouts. There is a concrete pad, I think, to show for it.

I would be interested in if you will take that case, which when I came here in the early eighties was the topic before this committee, with regard to the contribution it would make on the economy by giving us this technology we have seen fit not to proceed. The technology is being pursued by the Japanese and French to some extent; we have not concentrated on nuclear energy because of environmental concerns.

But what do we walk away from in that case? If you can just generalize relative to the contribution that France and Japan will generate and gain as a consequence of picking this up, as a matter of comparison, to try and address the Senator from Arkansas who is concerned with the estimated costs vis-a-vis the final costs and the return to the American taxpayer in jobs and economic productivity as a consequence of this tremendous technology from the standpoint of its feasibility?

I just wonder if anybody would care to say well, now, here is a glaring example of where, because of the political pressures, we walked away from that and France and somebody else has moved into it and their gain is our loss, or something to that effect, so I can get some measurement? I recognize there is a substantial difference, but nevertheless from the standpoint of funding there is a comparison.

Dr. LEDERMAN. Well, I am not an expert on Clinch River. I know about it vaguely as a citizen and a little bit about nuclear power. There was a technical issue there which had to do with very short term immediate prospects of how to best use nuclear energy. I think the consequences, as you mentioned, are vaguely what I understand, that we did lose an opportunity there, although I cannot really back that up very much.

The difference, though, is important to emphasize. I tried to show the SSC is a crucial phase in a long sequence of activities that have to do with a long-investment. We do not know—we, frankly, do not know and cannot estimate what the SSC will do as a societal thing. We think it is extremely important for a country like the United States of America, in spite of all of its anguish and all of its difficulties, to be in this business.

Because not to be in this business, that is to say we have to concentrate on what is going on today and tomorrow and next week, and we are not going to worry too much about what our grandchildren and their children will be up to. We are making this as an appeal out of the fabric of the history of science in the world. And that is the kind of argument we try to make.

All around us we see this kind of pessimism. Science is fundamentally an optimistic subject, and we think that that is what this country really needs, is a strong sense of optimism. And as I said before in view of the budget deficits, if you are going to understand in the long term how we are going to make this country economically confident, how we are going to make this country healthy, wealthy, and wise, I think things like the SSC have to be on our agenda as a portion of our resources, as an investment for the long term.

Senator MURKOWSKI. Anybody else want to try the return?

Dr. SCHWITTERS. I will just add a little to that. I think it—again, I know the Clinch River program as a citizen and what I have read about it technically. Another point, I would add, is we saw a case where simply the price of energy and other technologies made that project look relatively less interesting.

And I want to contrast that with the SSC where now there have been intense discussions within the scientific community; is it possible to do this science better, quicker, cheaper. And the answer keeps coming up no, and that is why we had this agonizing debate 3 years ago about the cost and the magnets.

Now in addition to the science, Leon has spoken about the long-range benefits. And here we are talking discoveries, talking—today's technologies were based on discoveries made at the beginning of this century; these are the discoveries of the next century. However we do know, and people have tried to analyze, the direct economic return through spinoff and through economic activity.

And generally—like any economic argument, you can believe that as you like—generally, those are quite favorable. That you get together a team of people here who are challenged by trying to do this science and they simply make a lot of very important inventions and contributions that spring forth in other areas of technology.

You discussed earlier this question of the MRI. Now another aspect of that was that the basic idea that you could take an external device and, without intrusion, examine things inside the body is the same as the detectors being able to examine inside the proton. In fact, the person who realized that idea of imaging was a physicist who received a Nobel Prize in medicine, Alan Cormack, for that idea which came from the detectors.

So, you know, the spinoffs and the ideas come in many different directions. I personally think that one has to be careful of exaggerated claims of spinoffs. I agree with your point, sir. On the other hand, all of science comes to bear on these things and it is very exciting, it is real, it is measurable, it happens in the economy.

But I come back to the argument that I tried to portray, is that we are putting together a group of people here, a team of engineers and scientists and secretaries and technicians. And our job is to responsibly challenge the unknown. And in putting together this team, I really believe the whole country benefits.

To take a very complex project—lots of problems that we have admitted to, we are discussing here, like any great endeavor—and responsibly manage that and complete that. In that process, I truly believe that the country gains in that confidence of being able to challenge the unknown, being able to do new things which we need to do if we are going to be a competitive society in the next century. So the science is one argument, the spinoffs is another, but somehow this team idea and the ability to manage responsibly the unknown I think are tremendous benefits that come about in a project like this.

Senator MURKOWSKI. Well that was the argument, of course, for setting a man on the moon.

Dr. SCHWITTERS. That is correct.

Senator BUMPERS. Senator Murkowski, I have to run. Let me just make a couple of points, if I may.

Senator MURKOWSKI. Thank you, Mr. Chairman.

Senator BUMPERS. No. 1, I misspoke myself when I said Vice President Quayle headed up the Competitiveness Council. That is a different Competitiveness Council and I am very pleased to say that.

And secondly, I want to ask any of you if you can tell me the status of the CERN project and can say categorically that CERN cannot discover what we are going to be looking for with our SCC.

Dr. **Schwitters**. Let me describe the status of the project. A very detailed design study has been executed at CERN to place superconducting rings of magnets in the existing left tunnel. The tunnel is approximately one-third the size and that sets the basic energy.

CERN has embarked on a modest magnet development program which has not yet produced a single full-size, full-scale operating magnet. That is the situation, where we were probably 5 years ago. CERN has slowed down the schedule of decision making on this project until late 1993 or 1994, before they go to their member states to make a final determination. CERN has begun to work with the scientific community to elicit their interest in the detectors. Those detectors will be reviewed starting in the fall; we began our reviews 2 years ago.

So I think what I can—furthermore, let me say the German Government has done an excellent study of their priorities in science that was published earlier this spring, known as the Grossman Report. There are some beautiful words in there about the value of big science and small science that I think is instructive for everyone to read.

However, they have made a strong point that CERN and the other new laboratory in Europe continue to exploit their existing machines. CERN has completed this marvelous machine in that tunnel. I mean it is a marvelous machine, it is doing excellent science now. And there was a sense, at least in the German report and I believe elsewhere in Europe, that it is very important now to not rush these huge facilities but to exploit fully their possibilities and, of course, to participate internationally in projects like the super collider.

So the consequences that the CERN plans, in my view now, indicate that there is no schedule advantage; that, if anything, the schedules are probably later than what we are talking about. It will be a good machine. CERN is an excellent laboratory; I have every confidence that technically it will work well. It simply will have one-third the window on the universe that we do, and I cannot tell you that they will not discover some great physics; I think they will.

Senator **Bumpers**. Can you assure us that you will?

Dr. **Schwitters**. Yes, I believe—we have studied very carefully this question; can we resolve experimentally the question of the origin of mass. That was the question that we posed in order to set the parameters of the SSC. And all of our colleagues here, and experts, felt that with the big jump, the 20 TEV per beam, it would be possible to answer that specific question, yes, sir.

Senator **Bumpers**. You would not want to guarantee that, would you, Dr. Schwitters.

The **Chairman**. Dr. Lederman, I think, wanted to say something.

Senator **Bumpers**. Dr. Lederman.

Dr. **Lederman**. I just wanted to, since Senator Bumpers is a good storyteller, tell about the people who came into the cave and said there are saber-toothed tigers out there, we have got to get out there and defend the cave. And this one guy appealed. He said I am busy. What are you doing? He said I am rubbing these sticks together. I promise you vast implications if this plan works. And it is a good thing they let him in there and rubbed sticks together because the Ice Age came.

Senator **BUMPERS**. Nobody laughed, Dr. Lederman.

[Laughter.]

Dr. **LEDERMAN**. The story of my life.

Senator **BUMPERS**. Thank you, Mr. Chairman.

The **CHAIRMAN**. Dr. Schwitters and Dr. Lederman and any of you, obviously to design a machine that has collisions at 40 TEV, it costs a lot of money to get the 40 TEV rather than the—what is CERN, if they build it, if they get the magnets? It will be, what, 12 TEV?

Dr. **SCHWITTERS**. 12 to 15, yes.

The **CHAIRMAN**. 12 to 15. And the obvious question, would you have built that machine at that additional cost with three times the circumference and three times the energy if you did not think it was necessary to find the origin of mass and the Higgs Boson and all of the other things that you have described here that you will look into?

Dr. **SCHWITTERS**. Well I answer with my career. The physicists are opportunists; they want to find the answers and do the experiments and share in the glory as best they can. But in looking at this question personally and scientifically, I have decided, and many of my colleagues have decided, that we had to take this larger view, that it was worth the investment to make sure that we could come to terms with this critical question.

The **CHAIRMAN**. Let me put on the record here before we close today the Inspector General's report. Mr. Cipriano, you ordered an Inspector General's report, did you not?

Mr. **CIPRIANO**. Yes, sir. I asked the Inspector General to look into some areas.

The **CHAIRMAN**. And that has not come out. It will come out, when—tomorrow or the day after?

Mr. **CIPRIANO**. I think there will be some briefings on the draft report in the next few days.

The **CHAIRMAN**. Do you know what it concludes?

Mr. **CIPRIANO**. It concludes—from the one I have seen and it is still in draft form. We asked them to look at this area of conventional construction. They started doing that last July. We got briefed on the findings and their recommendations like in December and started implementing them immediately and the report says that.

The report says they have looked at this area of conventional construction. They have decided we have a highly enthusiastic, very competent management team in place; the quality of construction is good; that tasks are generally well done; but that in the early phase of the construction program, some things cost more than they should have and we need to get those costs under control or else we are going to have an increase in costs from our baseline costs estimate.

We have taken the recommendations from that report; we have implemented those. The auditors have said that they agree that our implementation satisfies those concerns, and so we believe we have avoided those cost increases that might have occurred, due to those efficiencies.

The CHAIRMAN. As I understand it, initial construction exceeded the baseline or may exceed the baseline by something like $50 million.

Mr. CIPRIANO. Something like that.

The CHAIRMAN. And that because you saw this initial expansion and cost, you asked for an IG report which pointed out some deficiencies which you have corrected. The IG report so states. The $50 million which exceeds the baseline is obviously well within the $800 million contingency fund.

And that other parts of your contracting—for example, the tunnelling—are coming in under the baseline by 15 to 20 percent.

Mr. CIPRIANO. That is correct.

The CHAIRMAN. Would it be fair to say that the IG report which you requested has been useful, helpful? We have accepted their recommendations and it is not any particular—it is absolutely no cause for concern in terms of going over the estimated budget.

Mr. CIPRIANO. Yes, sir, I would agree with that. I think it is just the normal course of the way we are supposed to do business.

The CHAIRMAN. Well, gentlemen, I want to thank this panel. It has really been outstanding. I frankly would like even more time to delve into space time and some of its intricacies, and I think if we had enough time we could solve the Big Bang riddle right here.

[Laughter.]

The CHAIRMAN. But in any event, your testimony has been very helpful. I hope it has been watched by our colleagues. This has been beamed around the U.S. Senate by the wonders of television. It has been very helpful not just to this panel but to the Nation in what you do. Thank you very much.

[Whereupon, at 12.26 p.m. the hearing was adjourned.]

[An additional statement for the record follows:]

STATEMENT OF THE COUNCIL ON SUPERCONDUCTIVITY FOR AMERICAN COMPETITIVENESS

The Council on Superconductivity for American Competitiveness (CSAC) is pleased to submit this statement for the record on the Superconducting Super Collider. CSAC was established in 1987 and is the national trade association for the superconductivity industry in the United States. CSAC's primary mission is to facilitate national strategies to accelerate the commercial application of superconductivity across a broad range of technical disciplines. CSAC is a non-partisan association whose membership consists of Fortune 500 corporations and small entrepreneurial firms, national laboratories, universities, and research consortia.

CSAC strongly supports the development of the world's largest scientific research facility, the Superconducting Super Collider (SSC). CSAC supports the SSC because, in addition to providing invaluable scientific information, the SSC will also make a decisive contribution towards U.S. technology competitiveness by strengthening the U.S. industrial infrastructure in superconductor technologies.

As you know, superconductivity has been consistently identified as a "critical technology" for U.S. economic competitiveness in the 21st Century. The U.S. is now locked in an intense competition with Japan to determine which nation will eventually prevail in the race for worldwide leadership.

Progress in the development of superconductors has historically been linked to the particle accelerator field. Fermilab's Tevatron accelerator magnet system was the first large-scale application of superconductivity in the United States. Building these magnets advanced the critical technology issues of superconducting wire manufacturing, magnet design and testing, and cryogenic engineering.

Similarly, the SSC will result in the mass production of over 10,000 high quality, low-cost superconducting magnets, requiring industry to develop an infrastructure that can sustain a long-term commitment to high-technology manufacturing. This enormous development work in support of the SSC will: (1) enhance U.S. competitiveness in superconductivity; (2) directly complement existing Federal and industry funding for superconductivity R&D; and (3) provide the needed impetus for greatly expanded uses of superconductors in commercial applications.

Indeed, many of the envisioned applications of superconductivity have already attracted the attention of the Congress, including Magnetically Levitated Transportation Systems (Maglev), Superconducting Magnetic Energy Storage Systems (SMES), superconducting electric power generation and transmission applications, and superconducting digital microelectronics. Congressional support for the SSC will solidify the emerging industrial base in superconductor technologies which will allow for continued industrial efforts in these application fields.

Superconductivity is one of the most important scientific discoveries of the 20th Century. Expectations are that superconductivity will have a great impact on the economies and societies of all nations. Steady progress in superconductivity research has been made in the United States during this period. Substantially greater progress in superconductor technology can be expected as a result of the SSC as scientists and engineers develop ways to build and install superconducting magnets at a reasonable cost and operate them with high reliability.

Superconductivity is the ability of certain materials, when cooled to extremely low temperatures, to conduct an electrical current with no resistance and no losses. Scientists around the world consider superconductivity to be a unique phenomenon of nature that is in a class by itself, with high expectations for its application to energy electronics, transportation, and medicine.

Over the past 5 years, the intensity of worldwide research on superconductivity has produced impressive results. Important advances have come in rapid succession, and the measures of progress have broadened beyond critical temperature to include critical current capacity, critical magnetic field, processing, and other factors. Within the next 5 years, coercial magnetic field sensors and simple microwave devices operating at 77K are a distinct possibility. With diligence and patience, superconductivity could yield great dividends.

Total U.S. Federal government funding for superconductivity in Fiscal Year 1991 amounted to $241 million; $137 million of this total goes for high-temperature superconductivity R&D; $103 million goes for low-temperature work. In addition, the Superconducting Super Collider has received $1 billion in funding, which includes procurement of superconducting wire, magnets, and devices. Overall, the U.S. Department of Energy has the largest agency budget for both high and low-temperature R&D, at $128 million; followed by the Department of Defense at $73 million.

CSAC believes that the SSC will provide a great impetus to superconductivity development in the United States and will complement in a direct way the substantial Federal and industry funding for superconductivity research and development. The SSC will lay the foundation for U.S. competitiveness in the worldwide race for leadership. As the national trade association for the superconductivity industry in the United States, CSAC strongly believes that the SSC will directly contribute to U.S. competitiveness in this critical technology. We respectfully ask your support for the SSC.

Council on Superconductivity for American Competitiveness

MEMBERSHIP

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